GILT EDGE MINE SUPERFUND SITE

RUBY WASTE ROCK DUMP FINAL COVER SYSTEM GEOSYNTHETICS

FINAL DESIGN REPORT

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Introduction

The U.S. Bureau of Reclamation (Reclamation) was retained by the U.S. Environmental Protection Agency (EPA) to provide the necessary technical assistance to the State of South Dakota for closure and reclamation of the Gilt Edge Mine superfund site in Lawrence County, South Dakota. As part of the overall remediation effort, a final cap system for the Ruby Waste Rock Dump was designed to cover approximately 62 acres of spent ore and waste rock to prevent the formation of acid rock drainage (ARD) from the dump area due to water infiltration. Closure option 1 of the original Reclamation Closure Plan was chosen which generally required restructure and reduction of the Ruby dump slopes and to cap the dump in place to prevent future water infiltration and ARD into the groundwater and downstream into Ruby Gulch.

R. K. Frobel & Associates was retained as a subconsultant by Reclamation to provide technical assistance with the geosynthetics cap design, specifications and review of the overall closure plan for the Ruby Waste Rock Dump. In this regard, assistance was provided to the Design Team to review and generate drawings, review and generate calculations, design and coordinate laboratory testing, review laboratory test data, provide specification paragraphs and attend Design Team meetings and briefings at the EPA and State of South Dakota. Technical assistance will also be provided during construction to review contractor submittals and provide construction CQA training and oversight.

Heap Leach Pad Processed Ore - Base Bedding Layer

In the original Reclamation closure plan for the Gilt Edge Mine, it was decided to reuse and remove/replace as much of the on site material as possible in a final mass balance. In this regard, the existing Heap Leach Pad processed and oxidized ore was to be used as both the bedding material and the cover material for the geosynthetic barrier layer for the Ruby Waste Rock Dump cap system. However, due to the potential hazard of future ARD generation from the processed ore when placed above the geomembrane cover system, it was decided to use the processed ore for base layer bedding material only. Thus, the on site processed ore was a design requirement for soil interaction considerations when designing the cap system and required the review of the following characteristics:

Gradation, Maximum Particle Size and Angularity
Internal Shear Resistance (stability on slopes)
Density as a base layer (consolidation characteristics)
Smoothness as a base layer (roller compaction characteristics)

In addition to the soil material characteristics, interaction of the soil with geosynthetics needed to be addressed to determine the interface layer stability of the soil against the geomembrane under wetted surface conditions. Also, interaction during construction must be considered so that the processed ore material in contact with the geomembrane does not damage the geomembrane during placement of cover soils. To this end, high interface shear strength and good adhesion characteristics are important considerations.

The HLP spent oxidized ore material was inspected at the source for use as the base layer (bedding) soil for the geomembrane cap system. Samples of the HLP ore material were extracted and tested at the USBR laboratories and also prepared and sent to a third party laboratory for soil/geosynthetic interaction tests.

The processed ore material is generally classified as a poorly graded gravel with clay and sand (GP-GC) according to USBR physical properties tests. Although some of the gradation curves indicate presence of some 1.5 to 3.0 inch material (usually less than 1%) the majority of the spent oxidized ore can be considered 1.5 inch minus with 90% passing 1.5 inch sieve and over 80% passing the 1 inch sieve. Thus consideration for screening the material to 1 inch minus was eliminated from design due to cost considerations and the fact that the potential for damage to the geomembrane system would be minimal with a roller compacted base and careful placement of topsoil above the system (geomembrane is protected by either a geotextile layer or geonet composite on the top side).

Direct shear testing of the processed ore material under optimum moisture conditions indicates that the material will be stable on the final slopes of 3.5 : 1. USBR laboratory test results show an internal peak shear angle of $\phi = 47$ degrees and a post peak shear angle in excess of $\phi = 40$ degrees. This shear angle is primarily due to the gradation and angularity of the processed ore material and indicates stability even under moderate equipment compaction and densities.

Compaction test results obtained from USBR testing and a third party laboratory indicate that the processed spent ore has a maximum dry unit weight of between 123.5 and 128 pcf and optimum moisture content of between 9 and 11 %. Given the gradation of the ore, moisture content and compaction characteristics, it is recommended that the ore be placed in a minimum one foot thick base layer, smoothed and compacted with a vibratory roller. Vibratory roller compaction of the base layer under the geomembrane should result in a smooth compacted surface of greater than 95% SPD at + 2% of optimum moisture content. Thus, the presence of any 1 inch material on the surface should be minimal.

Processed, Crushed and Screened Rock - 18 inch Drain Layer

The soil material to be placed immediately above the geomembrane system on all slope areas must be relatively free draining, consistent in gradation and mechanical properties, stable and screened to 1 inch minus to help protect the geomembrane system during cover materials placement. Due to the State of South Dakota requirements to use borrow material from a nearby highway cut, the following materials were selected as candidate materials for the 18 inch thick layer directly above the geomembrane system:.

- Phyllite - a GW crushed and screened to 1 inch minus
- Trachyte - a GW screened to 1 inch minus (material available at the Gilt Edge site)
- Deadwood Formation - a GW crushed and screened to 1 inch minus
- Porphyry/Latite - a GW crushed and screened to 1 inch minus

All to the above materials were sampled and tested for mechanical characteristics, permeability and shear strength against the proposed geomembrane cover systems. In general, the Trachyte and Porphyry/Latite exhibited the best soil partical shape (angular) and stability under load and soaking. Also, these two materials exhibited better interface strength characteristics. The Phyllite was noted to have subangular flat particle structure which tended to break down upon soaking and loading and also exhibited the highest percentage of fines and lowest permeability. The Deadwood Formation material was also noted to be subangular and flat in particle structure but was not noted to break down upon soaking and under load. All four materials were highly porous due to the granular nature of the soils as tested. Appendix B contains the test data for mechanical properties, permeability characteristics and large scale direct shear.

Drainage Considerations - Cover Soils

As discussed above, one of the crushed and/or screened rock types generally classified as a GW will be placed in a minimum of one 18 inch thick layer directly above the geomembrane system as part of the cover soil. Due to the permeable nature of the rock layer and of the assumed variation as placed, a free draining layer will be required at the geomembrane/soil interface to prevent possible build up of seepage forces during potentially high rainfall events and saturated cover soil as well as during spring thaw of the cover system. As seepage forces result in the most frequent failures of slope covers, the following design considerations were addressed:

- cover soils will be highly variable and may be finer than desired
- cover soils are saturated (worse case condition)
- subsurface drainage at the toe of all slopes must be adequate and open to drains
- fine soil sediments may accumulate at toe of slopes above drain system
- potential for freezing of drain layer and soils immediately above geomembrane
- infiltration rate into drain layer due to saturated cover soils (worse case condition)
- design factor of safety for the geosynthetic drain flow rate must be > 1.5

It is assumed that the final cover at some point in its life will approach saturation due to weather conditions. If water flow in the soils layer immediately above the geomembrane is blocked, pore pressures will develop and affect the slope stability factor of safety approximately as follows:

$$FS_{sat} = 0.5 \tan \delta / \tan \beta$$

When the seepage forces are eliminated by using a high capacity geocomposite net or structured geomembrane surface drain, the slope stability factor of safety approximates the following:

$$FS = \tan \delta / \tan \beta$$

Once the soil is saturated, the gradient is equal to one and the infiltration velocity is equal to the permeability of the composite upper soil layer. The permeability of the full depth cover soils is dictated by the upper soil layers above the 18 inch rock layer and should approximate max k = 8.0 E-04 cm/sec in consideration of soil texture, required clay content and water holding capacity required for the root zone. For the Ruby Dump, maximum slope β will be 16 degrees and slope length L will be 150 ft (45.7 m). The flow rate into the drain should approximate the following:

$$Q\ (in) = k * L * 1 * \cos \beta = 3.51\ E\text{-}04\ cum/s\text{-}m.\ (1.62\ gpm/ft)$$

The flow out of the drain should approximate the flow in for design of lateral drainage at the toe of each slope. Thus the flow rate out of the drain per foot of width will be:

$$Q\ (out) = Q\ (in) = 3.51\ E\text{-}04\ cum/s\text{-}m\ (1.62\ gpm/ft)$$

The geonet composite or structured drain must posess a high transmissivity under load. According to Richardson and Zhao (1998), long term service reduction factors should be considered for a geonet composite to include the following:

- intrusion of geotextile RF(in) = 1.3 - 1.5 — use 1.3 for low loads (cap)
- creep of core or geotextile RF (c) = 1.1 - 1.4 — use 1.1 for low loads (cap)
- chemical clogging RF (cc) = 1.0- 1.2 — use 1.0 for upper soils
- biological clogging RF (bc) = 1.1 - 1.5 — use 1.1 for upper soils

For design purposes for the geocomposite drain, the total factor of safety for drainage in consideration of long term effects should be:

$$FS = RF\ (in) * RF\ (c) * RF\ (cc) * RF\ (bc) = 1.57$$

Thus, the design flow rate for the geocomposite drain layer should approximate the following:

$$Q = 1.57 \times 3.51\ E\text{-}04 = 5.51\ E\text{-}04\ cum/s\text{-}m \text{ or } 2.66\ gpm/ft.$$

The FS for the geocomposite drainage will be FS = Q(out)/Q(in) or 2.66/1.62 = 1.64 which will be more than adequate considering the high porosity of the granular layer directly above the geocomposite drain system.

Ruby Waste Rock Dump Slopes and Reshaping

Slopes on the lower east-west surface of the original Ruby Dump were approximately 2.5 :1 and 3 : 1 with slope lengths between existing benches in excess of 160 ft. There were 5 benches on the dump slope and each bench was originally constructed flat at approximately 30 ft in width. For design purposes, it was recommended that Reclamation consider reshaping of the entire Dump surface and reducing the slopes to 4 :1 dependent on mass balance and availability of processed ore for cover material.

Final design will require that all slopes be flattened to a maximum 3.5 : 1 or 16 degrees to enhance slope stability and provide for less surface erosion potential on the final vegetative soil layer. Also, final design for the reshaped slopes will incorporate a maximum 40.0 ft vertical height between benches and 25.0 ft. wide benches. This will result in maximum slope lengths of 150.0 ft. for design purposes of slope stability.

In the final slope design, a total of 10 benches will be incorporated on the dump slope and each bench will be sloped back into the dump section at 8% at the final grade prior to placement of the bedding material to facilitate lateral subsurface drainage on top of the geosynthetics, enhance slope stability at the base of each slope and allow for the construction of lateral surface drainage ditches in the cover material at each bench. Again, the addition of benches at maximum 40.0 ft. vertical is a critical design element for long term stability of the over 1800 ft long dump slope.

Due to the reshaping of the waste rock dump surface, filling of large depressions and shaping of the top and toe terrace areas (< 3 % slope), there will be approximately 17 acres of terrace or flat area and approximately 45 acres of slope and slope bench area.

Geomembrane Cover System

The Geomembrane Cover System will provide the requisite barrier layer to prevent water infiltration into the Ruby Waste Rock Dump and thus will prevent future generation of ARD. The primary barrier will be the geomembrane and the drainage layer immediately above the geomembrane will be a geosynthetic drain layer. The original closure plan suggested a 80 mil (2.0 mm) textured HDPE with a geonet composite.

Geomembrane Selection

Based on the site conditions, construction considerations, slopes, base layer soil, longevity requirements, acidic nature of interface soils and survivability during installation, a 60 mil (1.5 mm) minimum HDPE or LLDPE geomembrane was originally considered. After investigating the characteristics of the processed ore and the interface friction potential against a roller compacted processed ore surface, it was also decided to incorporate either a heavily textured surface or a structured texture surface that would provide high interface friction against the roller compacted ore. In consideration of additional toughness and resistance to installation stress, it was decided to use an 80 mil (2 mm) thick LLDPE geomembrane as opposed to a higher density HDPE. The LLDPE polymer will provide a more flexible material for installation purposes and better conformance to the base layer. To insure the roughest possible blown film texture, a minimum requirement for an asperity height of 15 mil will be part of the technical specifications for the textured geomembrane in addition to the performance requirement for a minimum $\delta = 28$ degrees interface friction angle with the compacted ore base layer. Historical large scale direct shear tests have shown friction angles for 1 inch minus angular soil to be in the range of $\delta = 26$ to 30 degrees for blown film texture HDPE or LLDPE and in excess of $\delta = 35$ degrees for structured (moulded surface) high profile HDPE or LLDPE. Thus, the two types of geomembrane systems designated for slope areas for specification purposes will be the following:

80 mil (2 mm) LLDPE Structured Geomembrane with Integral Drain Surface on one side and a spiked friction surface on the other.

80 mil (2 mm) LLDPE Blown Film with high profile rough surface texture on both sides of the sheet

Minimum physical/mechanical properties specifications for both will be as specified in the Geosynthetic Research Institute Standard GRI GM - 17 with the exception of asperity height (texture height) which will be specified at 15 mils (0.38 mm).

For the approximately 17 acres of terraced surface area, smooth 80 mil (2.0 mm) thick LLDPE will be specified. Minimum properties requirements will be as specified in the GRI GM - 17 standard for smooth LLDPE sheet.

In addition to standard properties requirements, the Gilt Edge Specifications will also require that the contractor submit third party large scale conformance testing for direct shear on all slope interfaces conducted in accordance with ASTM D 5321. The requirement that a minimum post peak large displacement interface friction angle of $\delta = 28$ degrees between all geosynthetic materials interfaces and geosynthetic/soil interfaces shall be specified for all slope areas. Minimum test parameter requirements of normal loads, conditions and test speeds shall also be specified.

Large Scale Interface Friction Testing - Slope Areas

Large Scale Interface Friction Testing was accomplished on the geomembrane cap systems in order to determine slope stability characteristics against the processed ore in wetted conditions and the crushed and/or screened rock cover materials in saturated conditions. The geomembrane cap system tested was the structured geomembrane with integral top surface drain layer and the blown film textured sheet with geonet composite. Both the upper surface and the lower surface were tested under loads similar to those that will occur in the slopes of the Ruby Dump. Testing was conducted at an independent laboratory experienced in soil interaction testing in accordance with ASTM D 5321 (Standard Test Method for Determining the Coefficient of Soil and Geosynthetic and Geosynthetic and Geosynthetic by the Direct Shear Method).

The cover system proposed for the Ruby Waste Rock Dump cover will be as follows from top to bottom:

6 inch thick - topsoil
24 inch thick - processed/amended soil and rock
18 inch thick - processed, crushed 1 inch minus rock

Geomembrane System A or B

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12 inch thick - roller compacted processed 1 inch minus ore base layer

Geomembrane System A or B alternatives are defined as follows

A - 80 mil (2 mm) LLDPE Structured Geomembrane with Integral Drain Surface and geotextile on top and spiked friction surface on bottom

B - 80 mil (2 mm) LLDPE Blown Film Textured (both sides) Geomembrane with Geonet Composite on the top side

The 18 inch thick layer directly above the geomembrane system A or B could be composed of one or more of the following materials taken from highway rock cuts:

- Phyllite - crushed and screened to1 inch minus
- Trachyte - screened to 1 inch minus (on site material at Gilt Edge)
- Deadwood Formation - crushed and screened to 1 inch minus
- Porphyry/Latite - crushed and screened to 1 inch minus

Actual gradation analysis of each of the above samples used in Direct Shear testing is shown in Appendix B. All were generally coarse grained sandy gravel (GW) with high porosity. The phyllite material was composed of more fine material and also exhibited the lowest interface shear characteristics. The Trachyte was composed of more stable angular material that is not subject to decomposition and also exhibited the highest interface shear characteristics.

The 12 inch thick base layer directly below the geomembrane system A or B is processed 1 inch minus ore taken from the Gilt Edge heap leach pile. This material will compact well with a vibratory roller providing a smooth base for the geomembrane system. Interface shear testing with the base ore material indicates a high shear resistance with the structured geomembrane of 32 degrees and good adhesion whereas the blown film textured surface exhibited the lowest interface shear angle of 29 degrees with low adhesion values. The following table is a summary ot the Large Scale Direct Shear test program results for both the upper cover soils and lower base layer processed ore vs. geomembrane system A and B. Actual laboratory data is included in Appendix B.

Large Scale Direct Shear Interface Friction Angles

Interface Soil	Geomembrane System A				Geomembrane System B			
	Peak (deg)	AD (psf)	LD (deg)	AD (psf)	Peak (deg)	AD (psf)	LD (deg)	AD (psf)
Processed Ore (base)	32	25	32	25	31	5	29	5
Phyllite (1" minus)	19	25	17	20	19	30	18	25
Trachite(1" minus)	37	30	37	30	37	10	37	10
Deadwood (1" minus)	36	5	33	0	35	10	33	0
Phorphry (1" minus)	33	40	33	40	34	5	34	5

Note: LD = Large Displacement Friction Angle; AD = Adhesion in PSF

Based on the above test results, the Phyllite rock source would not be a desireable material to be placed directly above either geomembrane system due to the exhibited low interface shear strength and subangular, flat particle shape. The Phyllite material was also observed to break down upon soaking and loading. The best performing material against either geomembrane system was the Trachite at 37 degrees which is approaching the internal shear of the material. The next best performing material would be the Phorphyry/Latite at 33 and 34 degrees. This material also exhibited high adhesion characteristics against Geomembrane system A due to the angular particle shape. The Deadwood Formation, although acceptable in interface shear, exhibited negligible adhesion to either geomembrane system primarily due to the subangular flat particle shape similar to the Phyllite material. Based on the above test results, it is recommended that the material to be placed directly above the geomembrane system be composed of either the Trachite or Porphyry/Latite.

Geotextile Selection - Geonet Composite or Structured Geomembrane

The geonet composite or structured geomembrane will require a filter geotextile regardless of the planar flow characteristics. As regards survivability during installation, the geotextiles must meet minimum strength requirements. For subsurface drainage applications, it is common to specify published AASHTO M288-96 class 2 geotextile minimum strength requirements as follows:

Grab Tensile Strength	ASTM D 4632	158 lbs
Tear Strength	ASTM D 4533	57 lbs
Puncture Resistance	ASTM D 4833	57 lbs
Hydraulic Burst	ASTM D 3786	200 psi

The above values should be a part of the Geomembrane System Specifications for the drain layer. In addition, the geotextile must meet filter criteria against the proposed rock layers. Based on the grain size analysis for the crushed and/or screened rock borrow sources, the general classification is a GW with as high as 6 percent passing the no. 200 sieve. Again, using the AASHTO filter requirements for subsurface drainage, the geotextile must posess a minimum permittivity of 0.5 sec-1 and a maximum AOS of 0.43 mm (no. 40 sieve). Thus a geotextile AOS of 40-60 and better will work. A further check on retention criteria (ability to retain upgradient soil) can be the criteria suggested by Holtz,. Christopher and Berg (1997) where:

$$O95/D85 < B \text{ wher } B = 1 \text{ for } Cu > 8$$

For the AASHTO M-288 minimum requirement of O95 = 0.43 mm and the D85 of the processed rock borrow at minimum 13 mm, O95/D85 = 0.033 < 1 and satisfies retention criteria. Thus, a nominal 6 oz/sq yd geotextile with an AOS of 70, minimum permittivity of 1.4 sec-1 and the above mechanical properties will satisfy survivability, filter, permittivity and retention criteria. However, for specification purposes and in consideration of minimum requirements for geomembrane protection and constructability on the slopes of the dump, a nominal 8 oz/sq yd geotextile will be specified for both the geonet composite and filter layer on the structured geomembrane with minimum physical/mechanical values as follows:

Grab Tensile Strength	ASTM D 4632	200 lb
Grab Tensile Elongation	ASTM D 4632	50 %
Trap Tear Strength	ASTM D 4533	80 lb
Puncture Strength	ASTM D 4833	130 lb
Burst Strength	ASTM D 3786	300 psi
Apparent Opening Size	ASTM D 4751	70-100 sieve size
Water Flow Rate	ASTM D 4491	110 gal/min/sqft

Geomembrane Cover System Slope Stability

Actual slope stability against sliding for all interfaces will be determined by large scale laboratory testing on the final selected material as required in the Specifications. This testing will be accomplished using simulated site conditions, processed ore, crushed and/or screened rock borrow and parameters as directed in the specifications using the Large Scale Interface Direct Shear Box in accordance with ASTM D 5321. A minimum friction angle of $\delta = 28$ degrees is required between all geosynthetic/geosynthetic or geosynthetic/soil interfaces.

The principles of one dimensional frictional force limit equilibrium analysis using classic wedge analysis was used in the design review of slope stability due to the fact that the potential for failure in the final cover system is usually linear along one of the interfaces utilizing geosynthetics. The potential failure plane allows for a straightforward calculation without the need for rotational failure surface analysis which is generally unacceptable due to the thin layers involved. In design review by limit equilibrium analysis, the following assumptions and parameters were selected as shown in the Appendix A calculations:

Base Soil Layer - Processed Ore, 1 inch minus with 95% SPD of 125 pcf
Cover Soil Layer - Processed/screened, 1 inch minus with the following densities:
$\gamma = 125$ pcf dry
$\gamma = 130$ pcf wet
Cover Soil Internal Shear - $\phi = 40$ degrees
Cover Soil Conditions - Saturated
Base Soil Layer Conditions - Wetted
Maximum Slope Length Between Benches - 150 ft
Maximum Slope Angle - $\beta = 16$ degrees (3.5 : 1)
Soil Cover Depth Maximum - 4.0 ft
Bench Width - 25.0 ft
Fully Drained Cover Soil/Geomembrane Interface (no seepage forces)
Maximum Frost Depth 3.5 ft

The basic cross section for the geomembrane cover system on the Ruby Waste Rock Dump is shown in figure 1. Based on the direct shear testing recently completed, the most critical interface of either option will be the lower surface texture geomembrane vs. processed ore under wetted conditions. Using the interface shear values in the previous summary table, the worse case shear would be the ore against the blown film texture or geomembrane system B. A conservative factor of safety against sliding can be assumed to be:

$$FS = \tan\delta / \tan\beta \quad = \tan 29 / \tan 16 = 1.9$$

This value may change based on required laboratory testing under site simulated conditions and using the actual materials as bid and as required in the specifications. The lowest estimated factor of safety against sliding was based on a maximum as built slope of 2.5 : 1 and resulted in a FS = 1.36 < 1.5 which was unacceptable and resulted in the decision to reshape the slopes to max 3.5 : 1.

Equipment Type and Travel vs. Slope Stability and Geomembrane Protection

Final specifications requirements must restrict the use of dozer equipment on the first 18 inches of cover placement over the geomembrane system to Low Ground Pressure (LGP) equipment of less than 5 psi ground pressure. This will restrict equipment to wide tracks (minimum width 2X lift thickness) to distribute dozer load and surface contact pressure. It is further recommended that the first lift be approximately 18 inches loose with maximum 10 inch soil height at LGP blade during distribution on the slopes from bottom of slope proceeding upslope. All cover soils on slopes must be placed from toe of slope proceeding upslope and lift thickness under equipment tracks must be monitored closely and continuously by both the contractor and CQA personnel.

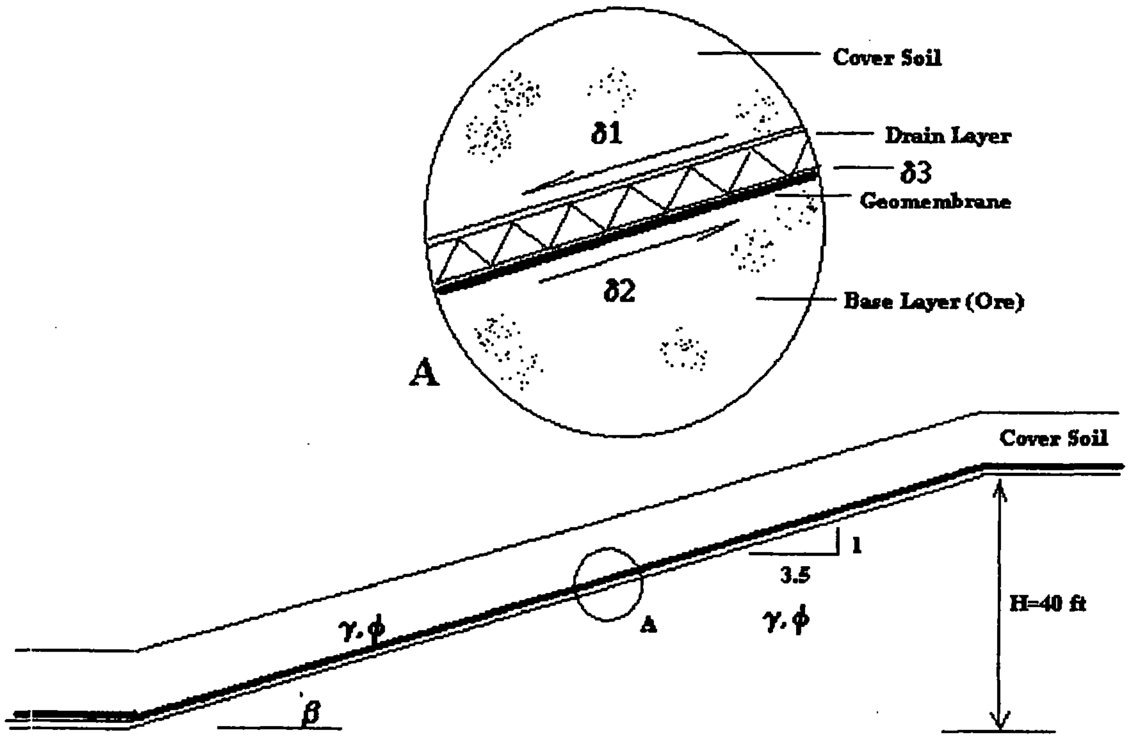


Figure 1. Geomembrane Cover System

Summary

Based on a review of available docmentation, laboratory test results on the processed ore, proposed rock cut materials, available soil/geosynthetics interaction test data and information available on the selected geosynthetics for the geomembrane cover system options, the following summary points are presented as regards the design adequacy for geosynthetics on the Ruby Waste Rock Dump cap.

1. Preliminary review of as-built slopes resulted in a decision to reshape the dump face and reduce slope angles to maximum 3.5 : 1 with benches every 40 ft of vertical height. This increases the FS against sliding to minimum of 1.9 based on worse case interface shear strength.

2. Due to the potential for highly variable coarse to fine grain soils adjacent to the geomembrane system and the possibility of saturated cover soils, a high capacity drainage layer was required at the top surface of the geomembrane to prevent build-up of seepage forces on the slopes.

3. In consideration of drain layer freezing and potential for ice blockage, cover height was increased to 4.0 ft based on mass balance recalculations and in consideration of potential for 3.5 ft frost depth at the mine location.

4. Benches were designed to provide both subsurface and surface lateral drainage and thus intercept all suburface drainage from geosynthetic drain layers as well as surface slope drainage during high rainfall events.

5. Benches were designed to provide stability of the over 1800 ft. long slope by reducing maximum slope lengths to 150 ft. and providing interlock of the final soil cover system at bench intercepts.

6. Geosynthetic materials designated as option A or B in the specifications were chosen for long term polymer stability considerations as well as high surface interface friction characteristics for all slope areas, geomembrane resistance to puncture, durability and long term high capacity flow for subsurface drainage design.

7. The final design incorporates on site materials (processed HLP ore) for the base bedding layer for the geomembrane and off-site crushed and/or screened material from highway rock cuts for cover materials. Again, based on the laboratory test results, it is recommended that the immediate 18 inch layer over the geomembrane system on all slope areas be restricted to the use of either Trachyte or Porphyry/Latite.

8. A minimum interface friction angle of $\delta = 28$ degrees is required between all interfaces and must be designated as a performance requirement in the specifications.

9. The final design specifications incorporate restrictions on cover soil placement to include LGP dozer equipment of less than 5 psi ground contact pressure for the first 18 inches of cover soil placement. This will greatly minimize problems associated with placement of cover soils and potential for damage.

10. The final design specifications require a smooth roller compacted base layer under the geomembrane system to reduce the potential for damage from the 1 inch minus ore bedding layer.

11. The final design specifications will allow for approximately 17 acres of smooth 80 mil (2.0 mm) LLDPE for all terraced areas with 3 % slope or less. The smooth LLDPE will be required to be covered with the 8 oz/sq yd non woven geotextile for protection during cover placement. As with the slope areas, the first 18 inches of cover material will be restricted to LGP (< 5 psi ground pressure) dozer equipment use.

12. The final design specifications will allow for placement of any of the selected highway cut borrow materials on the approximately 17 acres of terraced or flat areas with the same requirement for screening (screened to 1 inch minus) for material placed in the first 18 inch cover soil lift thickness.

APPENDIX A

GEOSYNTHETICS/SOILS STABILITY

Ruby Waste Rock Dump Geosynthetics Cap Stability

The following assumptions and sensitivity analysis are based on current laboratory data, the final maximum slope of 3.5H to 1.0V (β = 16 degrees) which is considered the best possible final constructed slope given site constraints, maximum allowable slope length between benches and mass balance requirements.

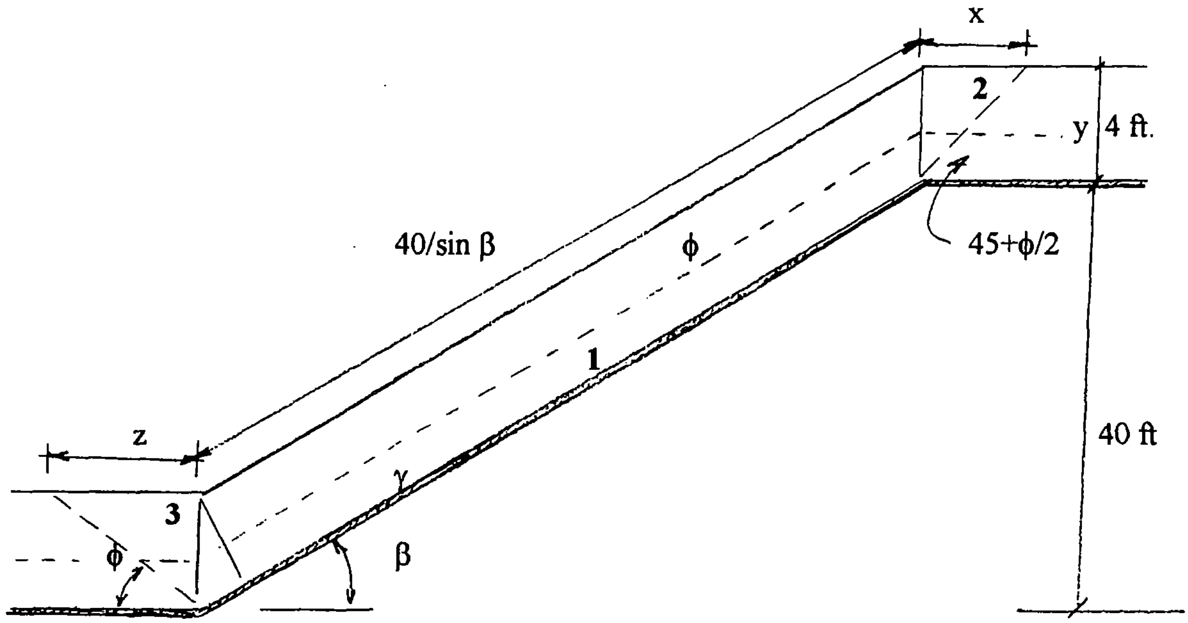
Assumptions for stability design analysis:

- Maximum slope - 3.5H : 1.0V or β = 16 degrees
- Maximum vertical height between benches - 40 ft.
- Minimum bench width - 25 ft.
- Maximum slope length based on above - 150 ft.
- Minimum FS against sliding failure - 1.5
- No Seismic forces to be considered at site (USBR)
- Worse case saturated cover soils condition
- Maximum frost depth - 3.5 ft.
- No gas generation within the rock dump
- Cover soil material will be variable (SDDOT highway borrow)
- Cover soil immediately above geomembrane system will be 1.5 ft. of one of the following: Phyllite (1 inch minus crushed and screened)
Trachyte (1 inch minus screened)
Deadwood Formation (1 inch minus crushed and screened)
Porphyry/Latite (1 inch minus crushed and screened
- Maximum cover soil unit weight - 130 pcf (γ sat)
- Maximum cover soil shear in drainage layer - ϕ = 40 degrees
- Minimum cover soil shear at drainage layer - ϕ = 30 degrees (Phyllite)
- Maximum cover soil depth - 4.0 ft.
- Base layer under geosynthetics - roller compacted processed ore
- Two geomembrane cover system options: A - 80 mil Structured geomembrane with integral drain system and cover geotextile and B - 80 mil Textured (blown extrusion) geomembrane with geonet composite drain layer

Stability analysis against a sliding failure

- Infinite slope two dimensional friction force limit equilibrium analysis
- Failure surface will be linear potentially along one of the interfaces of geomembrane system A or B
- Minimum FS = ratio of resisting forces to driving forces along a linear failure surface
- Sensitivity analysis - formulate as a function of max slope angle β (16 degrees)and critical interface friction angles δ (29 degrees for GM system B/ore base)
- No Seismic analysis required
- Interface between drain layer and upper soils layer not considered critical

Infinite Slope - long term with 4.0 ft cover



$y = 4/\cos\beta = 4.16$ ft

$\beta = 16$ degrees

$x = y \times 1/(\tan 45+\phi/2) = 1.94$ ft

$\phi = 40$ degrees

$z = y/\tan\phi = 4.95$ ft

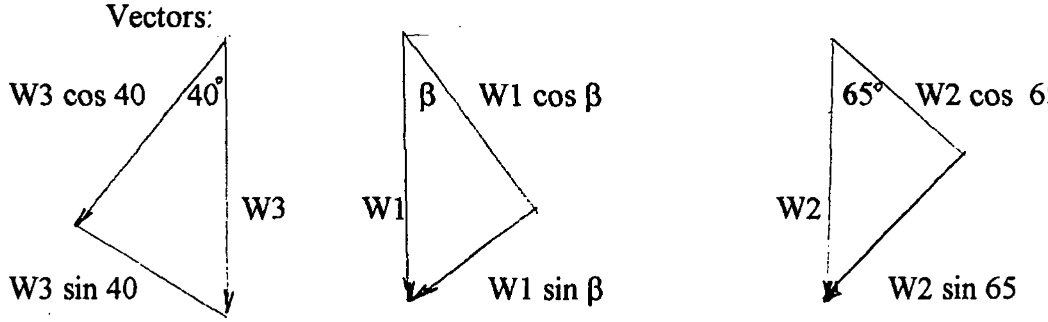
$\gamma = 130$ pcf

Active Wedge : $W1 = (40/\sin\beta)(4.0)(130) = 20{,}800/\sin\beta$ lb/ft (4 ft lift)
$= 7{,}800/\sin\beta$ lb/ft (1.5 ft lift)

$W2 = (4/\cos\beta)(1.94)(130)(1/2) = 524$ lb/ft (negligible)

Passive Wedge: $W3 = (4.95)(1.94)(130)(1/2) = 624$ lb/ft (negligible)

Vectors:



FS global check for final $\beta = 16$ degrees and $\phi = 40$ degrees (drain layer)

Resisting Forces:

A W1 $\cos \beta \tan \phi = 20800/\sin \beta (\cos \beta)(\tan \phi) = 60866$ lb/ft

B W2 $\cos 65 \tan \phi = 524 \cos 65 \tan 40 = 185$ lb/ft

C W3 $\cos \phi \tan \phi = 624 \cos 40 \tan 40 = 401$ lb/ft

Driving Forces:

X W1 $\sin \beta = 20800/\sin \beta (\sin \beta) = 20800$ lb/ft

Y W2 $\sin 65 = 524 \sin 65 = 475$ lb/ft

FS = A + B + C/ X + Y = 61452/20875 = 2.94 >> 1.5

Note: If the Phyllite material ($\phi = 30$ degrees) is assumed to be allowed on the slopes, the global FS will reduce considerably to approximately 1.8 and probably less due to the decomposition over time.

Static check on worse case interface for FS on sliding failure:

FS interface check for final $\beta = 16$ degrees and $\delta i = 29$ degrees (GM system B/ore)

A W1 $\cos \beta \tan \delta i = 20800/\sin \beta (\cos \beta)(\tan \delta i) = 40208$ lb/ft

B W2 $\cos 65 \tan \phi = 524 \cos 65 \tan 40 = 185$ lb/ft

C W3 $\cos \phi \tan \phi = 624 \cos 40 \tan 40 = 401$ lb/ft

Driving Forces:

X W1 $\sin \beta = 20800/\sin \beta (\sin \beta) = 20800$ lb/ft

Y W2 $\sin 65 = 524 \sin 65 = 475$ lb/ft

FS = A + B + C/ X + Y = 40208 + 185 + 401/ 20800 + 475

FS = 40794/ 21275 = 1.91 > 1.5

Static check on worse case interface for FS against sliding with LGP short term dozer loading with braking force on the 1.5 ft. thick drain layer. Again final β = 16 degrees and δi = 29 degrees (GM system B/ ore interface):

FS interface check for LGP dozer loading on 1.5 ft drain layer

LGP = D6HLGP W = 43590 lb with track width 3 ft = 7265 lb/ft
Downslope Braking force = 0.3 W = 2180 lb/ft
Total LGP loading = 9445 lb/ft = W4

Resisting Forces:

A $W1 \cos \beta \tan \delta i = 7800/\sin \beta (\cos 16)(\tan 29) = 15078$ lb/ft

B $W2 \cos 65 \tan \phi = 196 \cos 65 \tan 40 = 70$ lb/ft

C $W3 \cos \phi \tan \phi = 234 \cos 40 \tan 40 = 150$ lb/ft

D $W4 \cos \beta \tan \delta i = 9445 \cos 16 \tan 29 = 5032$ lb/ft

Driving Forces:

X $W1 \sin \beta = 7800/\sin\beta (\sin \beta) = 7800$ lb/ft

Y $W2 \sin 65 = 190 (\sin 65) = 172$ lb/ft

Z $W4 \sin \beta = 9445 (\sin 16) = 2603$

$FS = A + B + C + D/ X + Y + Z = 15078 + 70 + 150 + 5032/ 7800 + 172 + 2603$

$FS = 20330/10575 = 1.92 > 1.5$

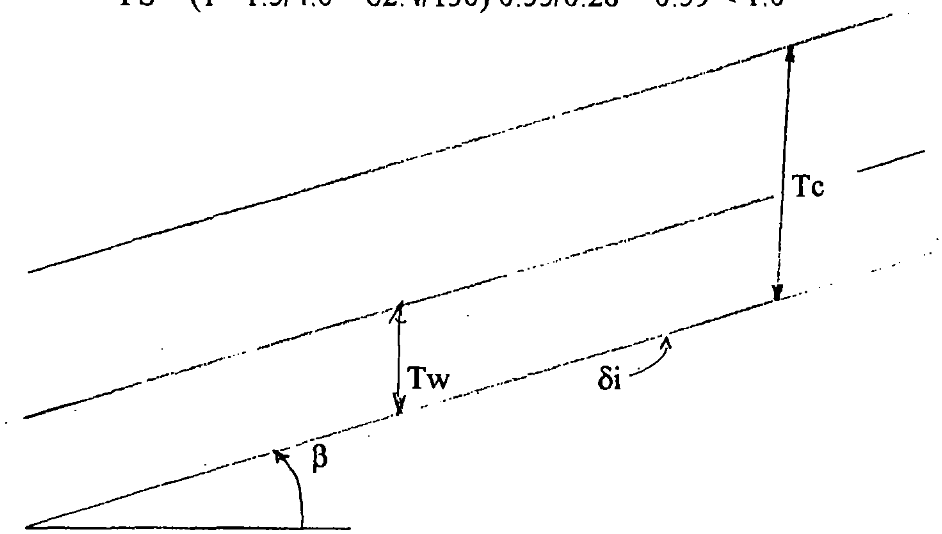
Seepage Forces in the 1.5 ft drain layer

The immediate interface at the top of the geomembrane may be subjected to seepage forces, especially considering highly variable borrow materials that may be contaminated with fines. Blockage to water flow at the geomembrane surface may be inhibited by ice during spring thaw or fines in the layer or due to segregation from the top soil layer. An estimated FS due to blockage in the 1.5 ft layer is as follows:

$FS = (1 - Tw/Tc * \gamma\omega/\gamma s) \tan \delta i/\tan \beta$

Where: Tw = water depth in layer
Tc = soil cover depth
γw = unit weight water
γs = sat unit weight soil
δi = lowest interface angle
β = slope angle in degrees

$FS = (1 - 1.5/4.0 * 62.4/130)\ 0.55/0.28 = 0.59 < 1.0$



The low FS indicates a drain layer immediately above the geomembrane is required if the soil drain layer becomes blocked. The FS with a geosynthetic drain layer directly above the geomembrane becomes $FS = \tan \delta i/\tan \beta = 1.94$. If the Phyllite material is allowed in the top cover drain layer, the critical interface now becomes Phyllite/GM system A at the top surface ($\delta i = 17$ degrees) and the resulting $FS = 1.06 < 1.5$. In addition to a drain layer, the geosynthetic composite or integral drain with geotextile provides protection for the geomembrane during soil cover placement.

Geosynthetic Drain Layer Flow Capacity

Assuming the soil type above the 1.5 ft drain layer is a GW but 1/4 inch minus for water retention or with amendments, the k max would be estimated at 8E10-04 cm/s. Under saturated conditions on the slope, the gradient can be assumed to be 1.0 through the saturated cover soil zone. Thus the infiltration velocity approximates the k (soil top layer) and Q (out) = Q (in) for the maximum slope length of 150 ft.

Q (in) = k * L * i * w * cos β = Q in cum/s-m (gpm/ft)
= 8E10-04 cm/s * 45.7 m * 1 * 1 * 0.96 = 3.51E-04 cun/s-m (1.62 gpm/ft)

Q (out) = Q (in) = 3.51E-04 cum/s-m (1.62 gpm/ft)

The geonet composite or integral drain must posess a high flow rate under load. As defined in the report, long term reduction factors (RF) for cap loading should be incorporated to provide a FS for drainage in consideration of long term effects:

FS = RF (intrusion) * RF (creep) * RF (chemical clogging) * RF (bio clogging)

For design purposes a FS of 1.57 was calculated based on reduction factors so that the design flow rate for the geocomposite drain layer should approximate the following:

Q = 1.57 * 3.51E-04 = 5.51E-04 cum/s-m = 2.66 gpm/ft

The FS for the geocomposite drainage will be FS = Q (out)/Q (in) = 2.66/1.62 = 1.64 assuming blockage of water flow in the 1.5 ft drain layer directly over the geocomposite. Actual flow in the geocomposite layer should be quite low in most cases on the slope areas given the high porosities of the proposed drain layer materials.

APPENDIX B

LABORATORY TEST PROGRAM
SGI TESTING SERVICES, LLC

Prepared for:

Bureau Of Reclamation
Construction Management Group
Denver Federal Center, Building 67
Mail Code D8160
Denver, Colorado 80225-0007

FINAL REPORT
LABORATORY TESTING SERVICES

GILT EDGE MINE SUPERFUND SITE
OU3 RUBY DUMP – REMEDIAL DESIGN

Prepared by:

SGI TESTING SERVICES, LLC

5775 Peachtree Dunwoody Road, Suite 11D
Atlanta, Georgia 30342

Project Number SGI1105

8 February 2002

CAVEAT

The reported results apply only to the materials and test conditions used in the laboratory testing program. The results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analysis unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. This testing report is submitted for the exclusive use of the client to whom it is addressed.

1. INTRODUCTION

The details of samples submitted for testing to SGI® Testing Services, LLC (SGI®), 5775 Peachtree Dunwoody Road, Suite 11D, Atlanta, Georgia 30342, are as follows:

Submitted by: Mr. David Paul

Client: U.S. Bureau Of Reclamation

Address: Construction Management Group
Denver Federal Center, Building 67, Mail Code D8160
Denver, Colorado 80225-0007

Materials tested: Geosynthetic Materials: 80-mil Agru Super Gripnet Structured LLDPE geomembrane, 80-mil GSE textured LLDPE geomembrane, TNS R080 nonwoven geotextile, And Tenax Tenflow 100-2 geocomposite.

Soil Materials: processed ore, Phyllite Cover Soil, Trachyte Cover Soil, Deadwood Formation Cover Soil, and Porphyry/Latite Cover Soil.

2. TEST PROGRAM

The test procedures and results are described in the following appendices:
Appendix A: Summary of Test Procedures
Appendix B: Soil Test Results
Appendix C: Hydraulic Transmissivity Test Results
Appendix D: Direct Shear Test Results

3. STORAGE AND DISPOSAL OF MATERIALS

Samples will be stored for 30 days from the date of this report and then discarded unless SGI® is informed otherwise.

* * * * *

REPORT REVIEW

REPORT PREPARATION BY:

Robert H. Swan, Jr.
President and CEO

TECHNICAL REVIEW BY:

Zehong Yuan, Ph.D., P.E.
Chief Technical Officer

APPENDIX A

SUMMARY OF TEST PROCEDURES

SUMMARY OF TEST PROCEDURES

SOIL TESTING

Test Methods

- ***Soil Compaction Testing:*** conducted in accordance with ASTM Standard Test Method D 698, *"Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lb/ft^3 (600 kN-m/m^3))"*.
- ***Particle-Size Analysis:*** conducted in accordance with ASTM Standard Test Method D 422, "*Particle-Size Analysis of Soils*", including hydrometer.
- ***Soil Classification*:** conducted in accordance with ASTM Standard Test Method D 2487, "*Classification of Soils for Engineering Purposes*".
- ***Hydraulic Conductivity*:** conducted in accordance with ASTM Standard Test Method D 2434, "*Permeability of Granular Soils (Constant Head)*".

Test Data Presentation

The soil test results are graphically presented in Appendix B for each of the five soils evaluated.

HYDRAULIC TRANSMISSIVITY TESTING

Test Method

The hydraulic transmissivity tests were performed in accordance with the ASTM Standard Test Method D 4716, *"Determining the (in-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head"*.

Sample Description and Test Configuration

The testing program consisted of two hydraulic transmissivity test series. Each test series consisted of two tests, each conducted at the same normal stress. The configuration of the test specimens for each hydraulic transmissivity test series is described, from top to bottom, as follows:

- top plate;
- Trachyte Cover Soil;
- TNS R080 nonwoven geotextile (Cover System A) or Tenax Tenflow 100-2 geocomposite (Cover System B);
- 80-mil Agru Super Gripnet structured LLDPE geomembrane with cylinder side up (Cover System A) or 80-mil GSE textured LLDPE geomembrane (Cover System B);
- bedding sand; and
- bottom plate.

Test Procedures

For each hydraulic transmissivity test series, the test specimens were set up in accordance with the above description and tested under the following general test conditions:

- a fresh specimen of the Trachyte Cover Soil was compacted by light hand tamping directly on top of the geotextile or geocomposite specimen
- Test normal stresses: 550 psf.
- Seating time: 15 minutes.
- Hydraulic gradient: 1.0.
- Specimen size: 12 in. by 12 in.
- each geosynthetic specimen was tested in the machine direction.

Test Data Presentation

The hydraulic transmissivity test results are graphically presented in Appendix C for each of the two cover systems evaluated.

DIRECT SHEAR TESTING

Test Method

The direct shear tests were performed in accordance with the ASTM Standard Test Method D 5321, *"Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and*

Geosynthetic Friction by the Direct Shear Method". The tests were conducted in a large direct shear device containing an upper and lower shear box. The upper shear box measured 12 in. by 12 in. in plan and 3 in. in depth. The lower shear box measured 12 in. by 14 in. in plan and 3 in. in depth.

Sample Description and Test Configuration

The testing program consisted of ten interface direct shear test series and one soil direct shear test series. Each interface direct shear test series consisted of three tests and the soil direct shear test series consisted of two tests, each conducted at a different normal stress. The configuration of the test specimens for each of the ten interface direct shear test series (see Photos 1 through 12 for typical test setup) and the soil direct shear test series (see Photos 23 through 30 for typical test setup) are described, from top to bottom, as follows:

<u>Test Series Numbers 1, 3, 5, and 7</u>

- Upper shear box: Phyllite Cover Soil (Test Series 1), Trachyte Cover Soil (Test Series 3), Deadwood Formation Cover Soil (Test Series 5), or Porphyry/Latite Cover Soil (Test Series 7);
- Tenax Tenflow 100-2 geocomposite;
- 80-mil GSE textured LLDPE geomembrane; and
- Lower shear box: processed ore.

Tested interface: upper cover soil against geocomposite

<u>Test Series Numbers 2, 4, 6, and 8</u>

- Upper shear box: Phyllite Cover Soil (Test Series 2), Trachyte Cover Soil (Test Series 4), Deadwood Formation Cover Soil (Test Series 6), or Porphyry/Latite Cover Soil (Test Series 8);
- TNS R080 nonwoven geotextile;
- 80-mil Agru Super Gripnet structured LLDPE geomembrane; and

- Lower shear box: processed ore.

Tested interface: upper cover soil against geotextile

Test Series Numbers 9 and 10

- Upper shear box: processed ore;
- 80-mil GSE textured LLDPE geomembrane (Test Series 9) or 80-mil Agru Super Gripnet structured LLDPE geomembrane (Test Series 10);
- Tenax Tenflow 100-2 geocomposite (Test Series 9) or TNS R080 nonwoven geotextile (Test Series 10); and
- Lower shear box: Trachyte Cover Soil.

Tested interface: processed ore against geomembrane

Test Series Number 11

- Upper shear box: Phyllite Cover Soil
- Lower shear box: Phyllite Cover Soil.

Tested interface: mid-plane of cover soil

Test Procedures

For each direct shear test series, the test specimens were set up in accordance with the above description and tested under the following general test conditions:

- fresh specimens of the processed ore were compacted by hand tamping. The initial target compaction conditions (i.e., dry unit weight and moisture content) for the ore material correspond to 95% of maximum dry unit weight and one (1) percentage point above the optimum moisture as determined from the standard Proctor compaction test performed by SGI® and presented in Appendix B.
- fresh specimens of each cover soil were compacted by light hand tamping. There were no initial target dry unit weight conditions specified and each soil

was placed at it's as-received moisture content.

- each fresh specimen of geocomposite, geotextile, or geomembrane, which was the intended shear surface, was trimmed from each bulk sample and attached to the lower shear box with mechanical compression clamps.
- Test normal stresses: 225, 550, and 1100 psf.
- Constant shear displacement rate: 0.04 in/min.
- Shear box size: 12 in. by 12 in.
- each geosynthetic specimen was tested in the machine direction.
- each test was sheared until a minimum total shear displacement of 2 in. was achieved.

Failure Modes

For all eleven-test series, sliding (shear failure) occurred at the intended interface or through the mid-plane of the soil during each test. There was no visually observed damage (i.e., stretching, puncture holes, scratches, etc.) to any of the geosynthetic interface shear surfaces as documented in Photos 13 through 22.

Test Data Presentation

For each of the direct shear tests, the total-stress shearing resistance was evaluated for each applied normal stress. The test data were plotted on a graph of shear force versus horizontal displacement. The resulting plots are presented in Appendix D. The peak value of shear force was used to calculate the peak shear strength. The large displacement shear strength (τ_{LD}) was calculated by using the shear force measured at the end of each test. No area correction was used when computing normal and shear stresses because each test was performed using a constant effective sample area (i.e., the area of the lower shear box was larger than that of the upper shear box).

The calculated shear strengths were plotted on a graph of shear stress versus normal stress. The results were used to evaluate total-stress peak and large displacement shear strength envelopes. A best-fit straight line was drawn through the data points from each test series to obtain the corresponding total-stress peak and large displacement shear strength friction angles and adhesions. The coefficient of correlation (R^2), a standard statistical indicator of how well the best-fit line matches the test data, was obtained for each best-fit line. The summary plots of shear stress versus normal stress with the corresponding friction angles, adhesions, and R^2 values for each test series are also presented in Appendix D.

For each test series, it is noted that the reported total-stress shear strength parameters of friction angle and adhesion were determined based on the best-fit straight line drawn through the test data on a plot of shear stress versus normal stress. Caution should be exercised in using these shear strength parameters for applications involving normal stresses outside the range of stresses covered by each test series.

APPENDIX B

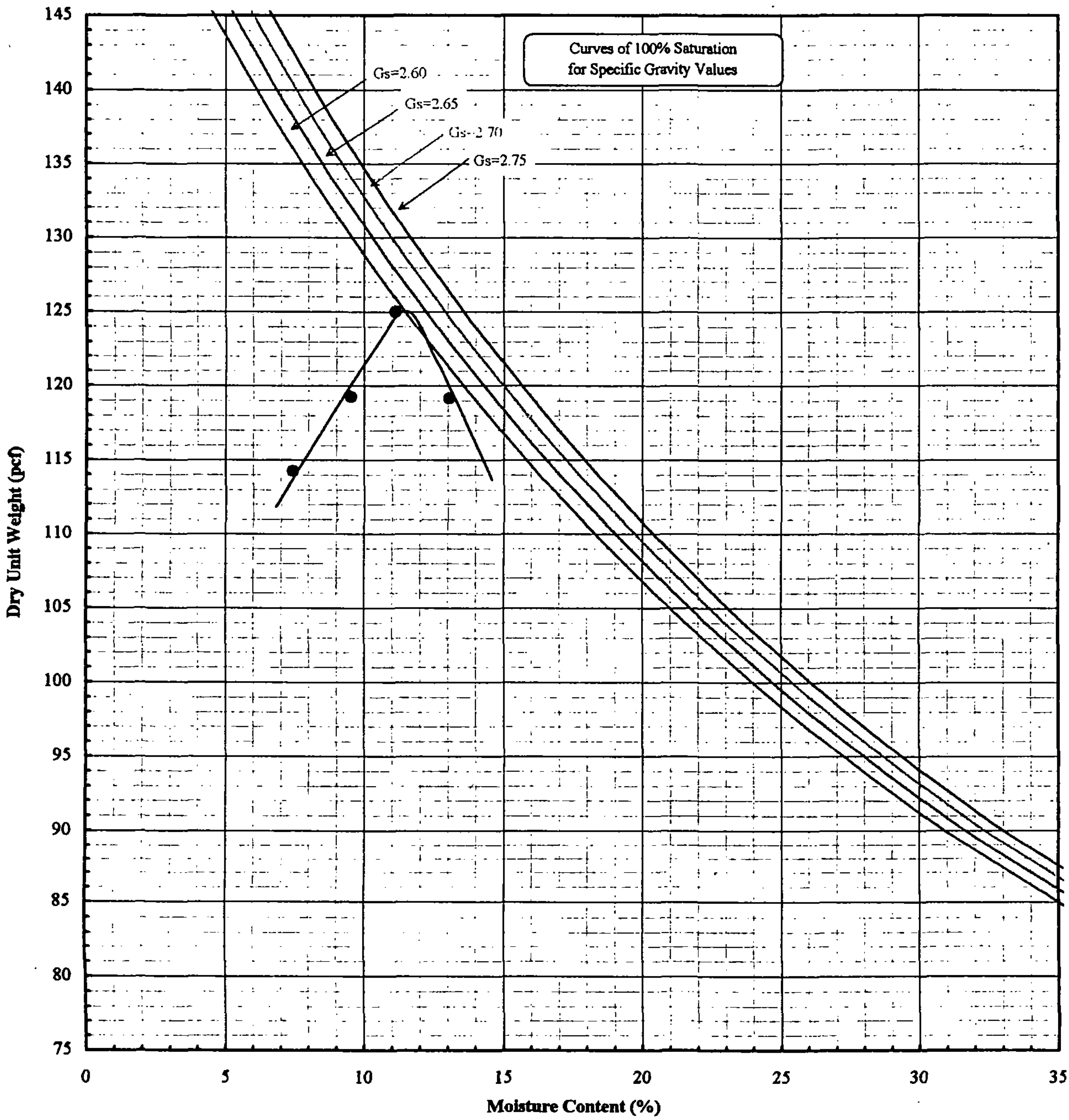
SOIL TEST RESULTS

SGI TESTING SERVICES, LLC

5775 Peachtree Dunwoody Road, Suite 11D, Atlanta, Georgia 30342
Ph: (404) 256 9939 Fax: (404) 705 9300

Project Name: Gilt Edge Mine Superfund Site
Project No: SGI1105
Client Sample ID: Processed Ore
Lab Sample No: AL8909

ASTM D698 — **COMPACTION MOISTURE-DENSITY RELATIONSHIP** — Standard - Method C



Client Sample ID.	Lab Sample No:	Maximum Dry Unit Weight (pcf)	Optimum Moisture Content (%)	Remarks
Processed Ore	AL8909	125.0	11.2	

Note(s):

As-Received Moisture Content Was 1.2 %

Reviewed by: RHS Date: 2/8/2002
Robert H. Swan, Jr., President and CEO

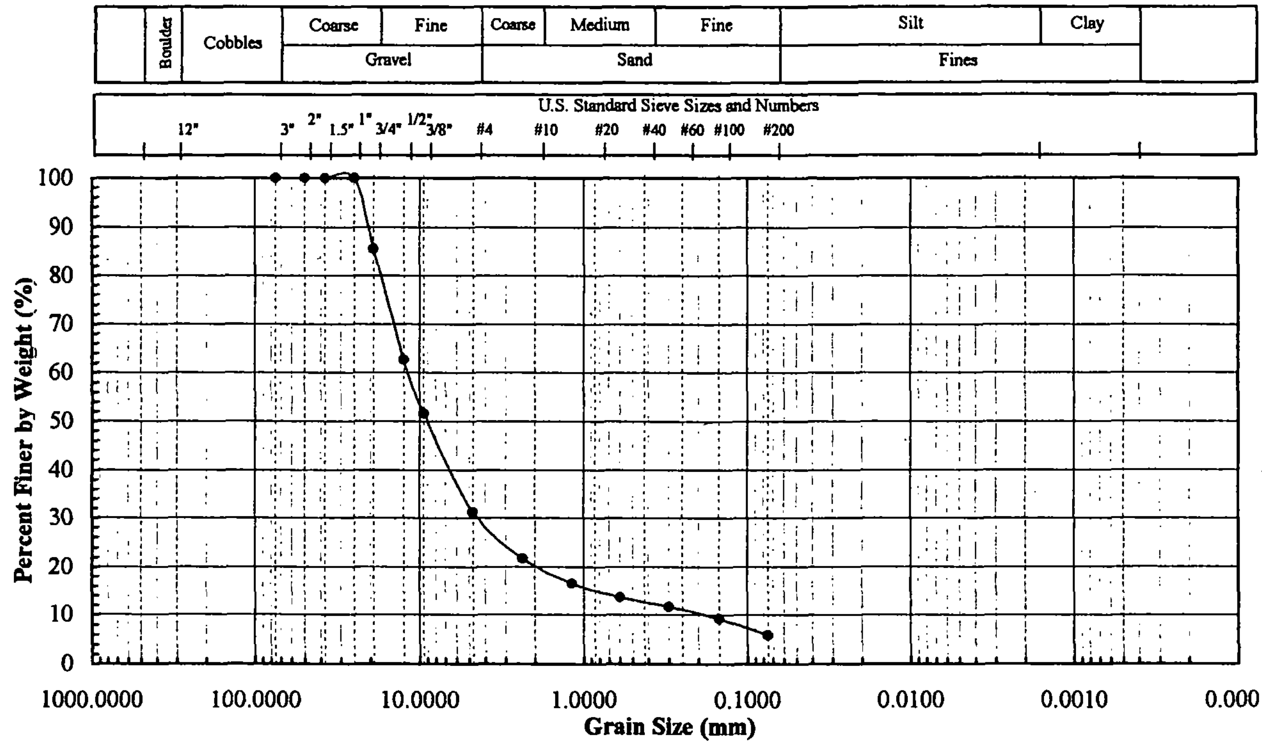
al8909.soil.proctor.xls

SGI TESTING SERVICES, LLC	Project Name: Gilt Edge Mine Superfund Site
5775 Peachtree Dunwoody Road, Suite 11D, Atlanta, Georgia 30342	Project No: SGI1105
Ph: (404) 256 9939 Fax: (404) 705 9300	Client Sample ID: Phyllite Cover Soil
	Lab Sample No: AL8910

ASTM D 2216, D 1140, D 422, C 136, D 4318, D 2487

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits, Classification

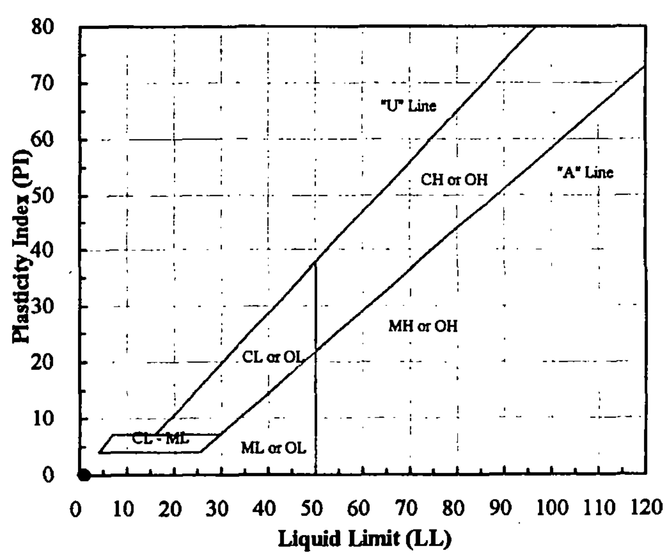


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	100.0
3/4"	19	85.6
1/2"	12.5	62.7
3/8"	9.5	51.6
#4	4.75	31.2
#8	2.36	21.7
#16	1.180	16.6
#30	0.600	13.6
#50	0.300	11.6
#100	0.150	9.3
#200	0.075	6.0

Hydrometer Particle Diameter (mm)	% Finer
0.0288	
0.0184	
0.0109	
0.0079	
0.0012	

Gravel (%):	68.8
Sand (%):	25.2
Fines (%):	6.0
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	62.5
Coeff. Curv. (Cc):	7.4



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (%)	PL (%)	PI (-)	Engineering Classification
Phyllite Cover Soil	AL8910	0.5	6.0	-	-	-	GP-GM (Poorly graded gravel with silt and sand)

Note(s):

The soil particles were mostly flat (plate-like) in shape having subangular to subrounded angularity.

Reviewed by: RHS Date: 2/8/2002

al8910.soil.index.xls

Robert H. Swan, Jr., President and CEO

SGI TESTING SERVICES, LLC

5775 Peachtree Dunwoody Road, Suite 11D, Atlanta, Georgia 30342
Ph: (404) 256 9939 Fax: (404) 705 9300

RIGID WALL PERMEABILITY TEST
ASTM D2434

Project Name:	Gilt Edge Mine Superfund Site
Project Number:	SGI1105
Client Project Number:	N/A
Client/Site ID:	Phyllite Cover Soil
Sample Number:	AL8910
Material Type:	Crushed Rock (1 in. minus)
Expected/Specified Value:	N/A
Date Received:	15 November 2001

Specimen Number	Specimen Initial Conditions					Permeant	Gradient Range	Hydraulic Conductivity
	Spec. Prep. [(2)] (-)	Spec. Length (cm)	Spec. Diameter (cm)	Dry Unit Weight (pcf)	Moisture Content (%)	Liquid [(3)] (-)	(-)	(cm/s)
1	R	31.0	10.2	107.8	0.5	TW	0.48	2.8E-1

Notes:

1. Constant head test procedures were followed during the testing.
2. Specimen preparation: ST = Shelby Tube, R = Remolded, B = Block Sample
3. Type of permeant liquid: TW = Tap Water, DTW = Deaired Tap Water, DDI = Deaired Deionized Water

* Deviations:

Laboratory temperature at 21±3 °C.

Test specimen final conditions are not presented.

SGI TESTING SERVICES, LLC

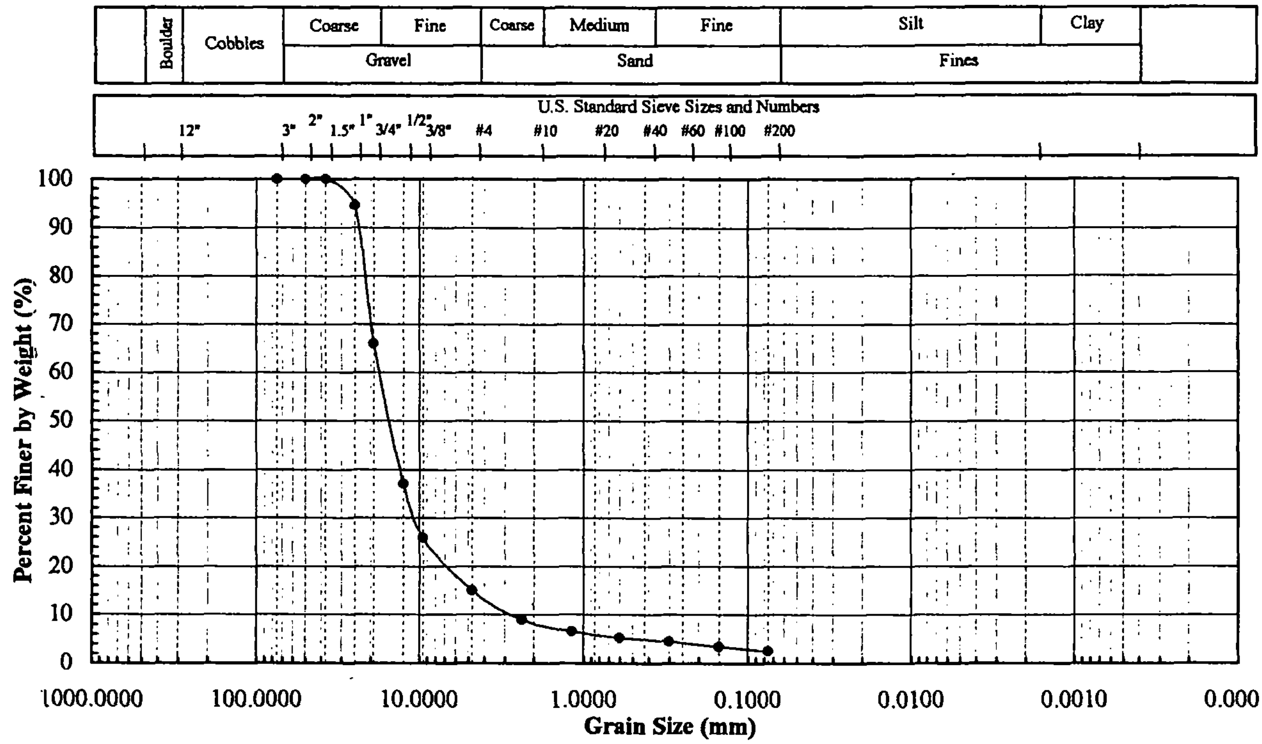
5775 Peachtree Dunwoody Road, Suite 11D, Atlanta, Georgia 30342
Ph: (404) 256 9939 Fax: (404) 705 9300

Project Name:	Gilt Edge Mine Superfund Site
Project No:	SGI1105
Client Sample ID:	Trachyte Cover Soil
Lab Sample No:	AL8911

ASTM D 2216, D 1140, D 422, C 136, D 4318, D 2487

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits, Classification

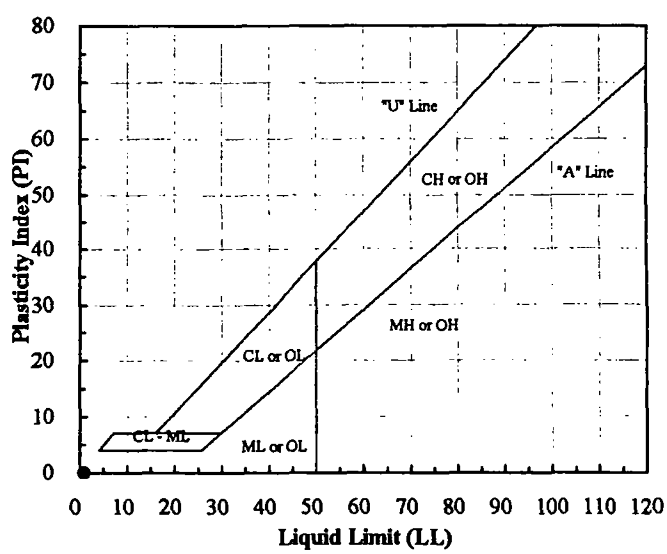


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	94.6
3/4"	19	66.0
1/2"	12.5	37.1
3/8"	9.5	25.9
#4	4.75	14.9
#8	2.36	9.0
#16	1.180	6.6
#30	0.600	5.3
#50	0.300	4.5
#100	0.150	3.5
#200	0.075	2.5

Hydrometer Particle Diameter (mm)	% Finer
0.0288	
0.0184	
0.0109	
0.0079	
0.0012	

Gravel (%):	85.1
Sand (%):	12.4
Fines (%):	2.5
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	6.9
Coeff. Curv. (Cc):	2.6



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (%)	PL (%)	PI (-)	Engineering Classification
Trachyte Cover Soil	AL8911	1.2	2.5	-	-	-	GW (Well-graded gravel)

Note(s):

The soil particles were angular to subangular in angularity.

Reviewed by: RHS Date: 2/8/2002
Robert H. Swan, Jr., President and CEO

al8911.soil.index.xls

SGI TESTING SERVICES, LLC

5775 Peachtree Dunwoody Road, Suite 11D, Atlanta, Georgia 30342
Ph: (404) 256 9939 Fax: (404) 705 9300

RIGID WALL PERMEABILITY TEST
ASTM D2434

Project Name:	Gilt Edge Mine Superfund Site
Project Number:	SGI1105
Client Project Number:	N/A
Client/Site ID:	Trachyte Cover Soil
Sample Number:	AL8911
Material Type:	Crushed Rock (1 in. minus)
Expected/Specified Value:	N/A
Date Received:	15 November 2001

Specimen Number	Specimen Initial Conditions					Permeant	Gradient Range	Hydraulic Conductivity
	Spec. Prep. [(2)] (-)	Spec. Length (cm)	Spec. Diameter (cm)	Dry Unit Weight (pcf)	Moisture Content (%)	Liquid [(3)] (-)	(-)	(cm/s)
1	R	25.4	15.2	93.3	1.2	TW	0.33	2.8E+0

Notes:

1. Constant head test procedures were followed during the testing.
2. Specimen preparation: ST = Shelby Tube, R = Remolded, B = Block Sample
3. Type of permeant liquid: TW = Tap Water, DTW = Deaired Tap Water, DDI = Deaired Deionized Water

* Deviations:
Laboratory temperature at 21±3 °C.
Test specimen final conditions are not presented.

SGI TESTING SERVICES, LLC

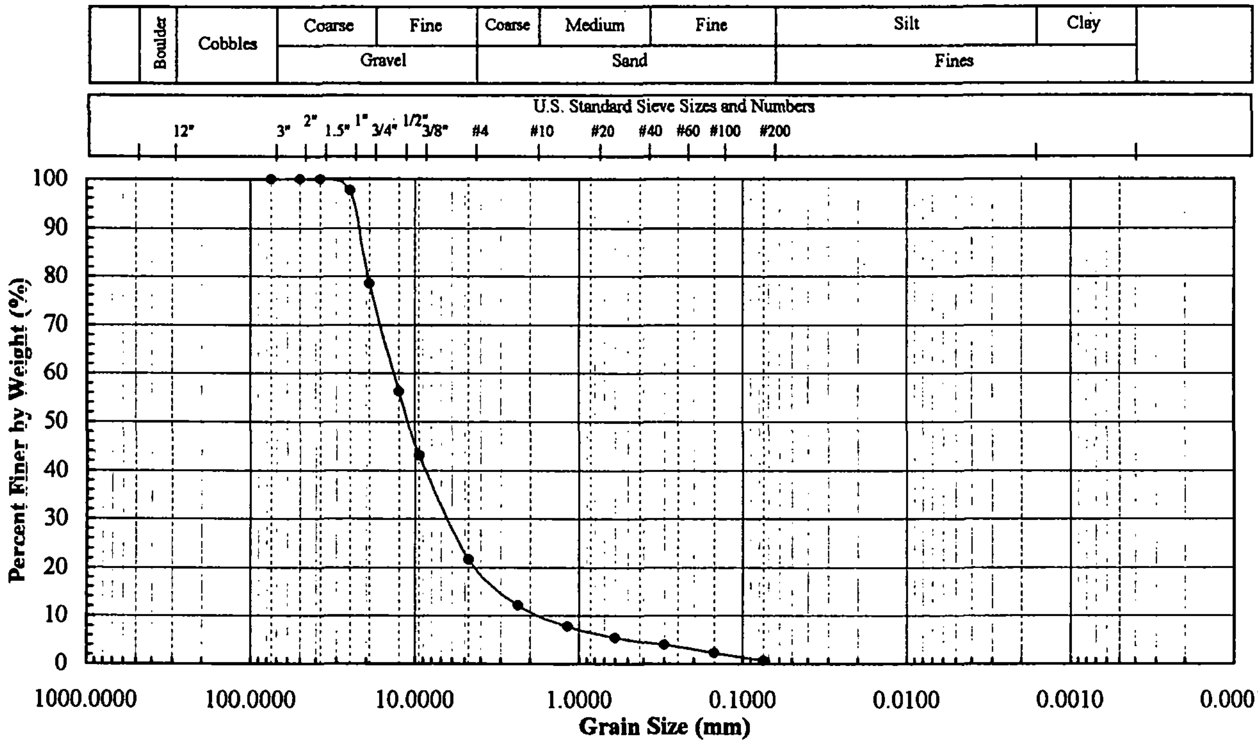
5775 Peachtree Dunwoody Road, Suite 11D, Atlanta, Georgia 30342
Ph: (404) 256 9939 Fax: (404) 705 9300

Project Name: Gilt Edge Mine Superfund Site
Project No: SGI1105
Client Sample ID: Deadwood Formation Cover Soil
Lab Sample No: AL8912

ASTM D 2216, D 1140, D 422, C 136, D 4318, D 2487

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits, Classification

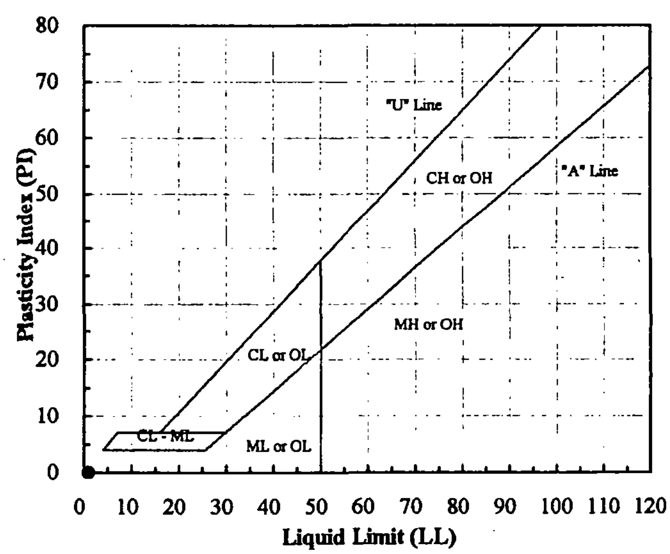


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	97.6
3/4"	19	78.4
1/2"	12.5	56.2
3/8"	9.5	43.1
#4	4.75	21.7
#8	2.36	12.2
#16	1.180	7.8
#30	0.600	5.4
#50	0.300	4.0
#100	0.150	2.3
#200	0.075	0.7

Hydrometer Particle Diameter (mm)	% Finer
0.0288	
0.0184	
0.0109	
0.0079	
0.0012	

Gravel (%):	78.3
Sand (%):	21.0
Fines (%):	0.7
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	8.2
Coeff. Curv. (Cc):	1.6



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (%)	PL (%)	PI (-)	Engineering Classification
Deadwood Formation Cover Soil	AL8912	0.4	0.7	-	-	-	GW (Well-graded gravel with sand)

Note(s):

The soil particles were mostly flat (plate-like) in shape having subangular to subrounded angularity.

Reviewed by: RHS Date: 2/8/2002
Robert H. Swan, Jr., President and CEO

SGI TESTING SERVICES, LLC

5775 Peachtree Dunwoody Road, Suite 11D, Atlanta, Georgia 30342
Ph: (404) 256 9939 Fax: (404) 705 9300

RIGID WALL PERMEABILITY TEST
ASTM D2434

Project Name:	Gilt Edge Mine Superfund Site
Project Number:	SGI1105
Client Project Number:	N/A
Client/Site ID:	Deadwood Formation Cover Soil
Sample Number:	AL8912
Material Type:	Crushed Rock (1 in. minus)
Expected/Specified Value:	N/A
Date Received:	15 November 2001

Specimen Number	Specimen Initial Conditions					Permeant	Gradient Range	Hydraulic Conductivity
	Spec. Prep. (2) (-)	Spec. Length (cm)	Spec. Diameter (cm)	Dry Unit Weight (pcf)	Moisture Content (%)	Liquid (3) (-)	(-)	(cm/s)
1	R	25.4	15.2	102.8	0.4	TW	0.33	1.2E+0

Notes:

1. Constant head test procedures were followed during the testing.
2. Specimen preparation: ST = Shelby Tube, R = Remolded, B = Block Sample
3. Type of permeant liquid: TW = Tap Water, DTW = Deaired Tap Water, DDI = Deaired Deionized Water

* Deviations:
Laboratory temperature at 21±3 °C.
Test specimen final conditions are not presented.

SGI TESTING SERVICES, LLC
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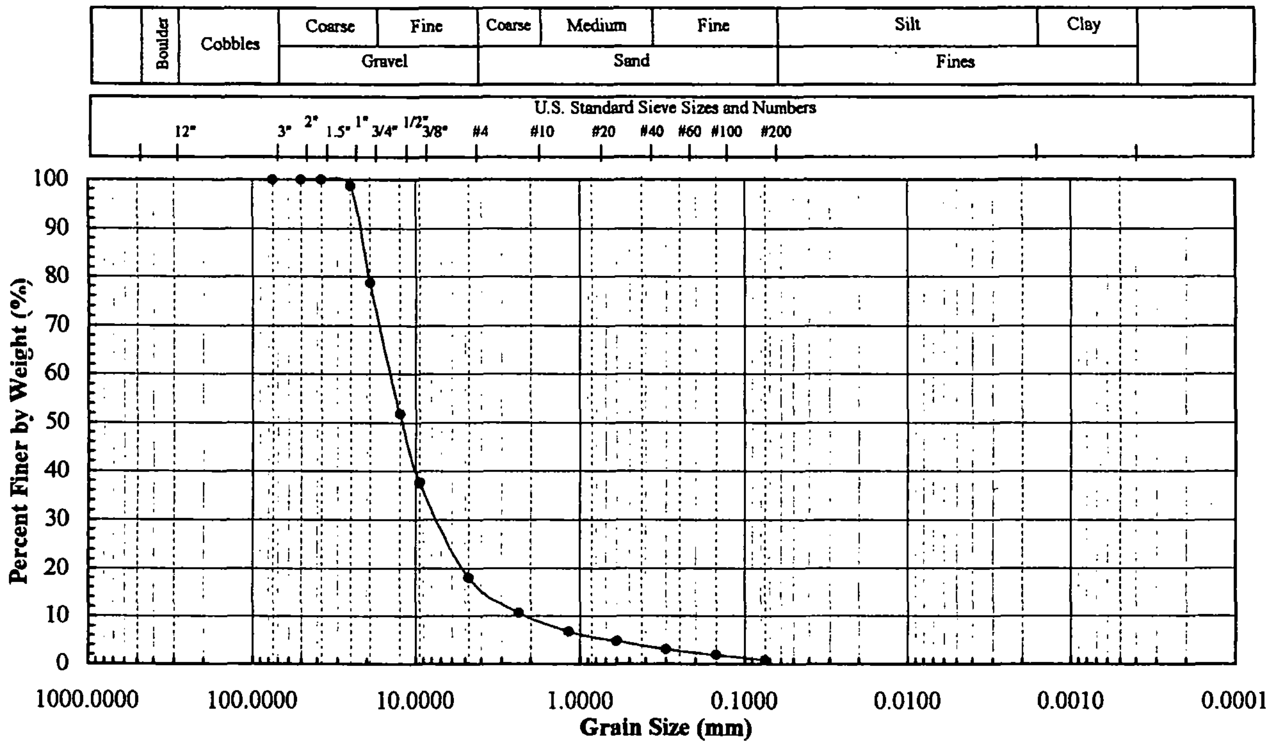
Ph: (404) 256 9939 Fax: (404) 705 9300

Project Name:	Gilt Edge Mine Superfund Site
Project No:	SGI1105
Client Sample ID:	Prophyry/Latite Cover Soil
Lab Sample No:	AL8913

ASTM D 2216, D 1140, D 422, C 136, D 4318, D 2487

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits, Classification

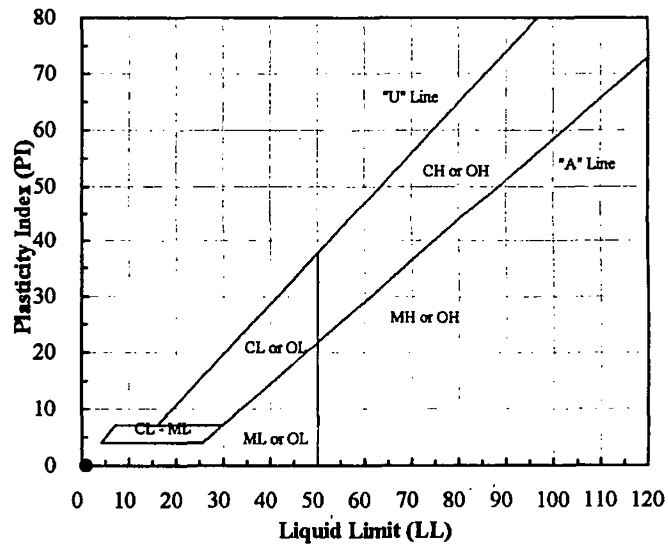


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	98.7
3/4"	19	78.7
1/2"	12.5	51.8
3/8"	9.5	37.6
#4	4.75	18.0
#8	2.36	10.7
#16	1.180	6.8
#30	0.600	4.7
#50	0.300	3.1
#100	0.150	1.9
#200	0.075	0.8

Hydrometer Particle Diameter (mm)	% Finer
0.0288	
0.0184	
0.0109	
0.0079	
0.0012	

Gravel (%):	82.0
Sand (%):	17.2
Fines (%):	0.8
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	7.1
Coeff. Curv. (Cc):	1.7



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (%)	PL (%)	PI (-)	Engineering Classification
Prophyry/Latite Cover Soil	AL8913	0.2	0.8	-	-	-	GW (Well graded gravel with sand)

Note(s):

The soil particles were subangular to subrounded in angularity.

Reviewed by: RHS Date: 2/8/2002
Robert H. Swan, Jr., President and CEO

SGI TESTING SERVICES, LLC

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RIGID WALL PERMEABILITY TEST
ASTM D2434

Project Name:	Gilt Edge Mine Superfund Site
Project Number:	SGI1105
Client Project Number:	N/A
Client/Site ID:	Porphyry/Latite Cover Soil
Sample Number:	AL8913
Material Type:	Crushed Rock (1 in. minus)
Expected/Specified Value:	N/A
Date Received:	15 November 2001

Specimen Number	Specimen Initial Conditions					Permeant	Gradient Range	Hydraulic Conductivity
	Spec. Prep. (2) (-)	Spec. Length (cm)	Spec. Diameter (cm)	Dry Unit Weight (pcf)	Moisture Content (%)	Liquid (3) (-)	(-)	(cm/s)
1	R	25.4	15.2	94.4	0.2	TW	0.33	5.4E-1

Notes:

1. Constant head test procedures were followed during the testing.
2. Specimen preparation: ST = Shelby Tube, R = Remolded, B = Block Sample
3. Type of permeant liquid: TW = Tap Water, DTW = Deaired Tap Water, DDI = Deaired Deionized Water

* Deviations:

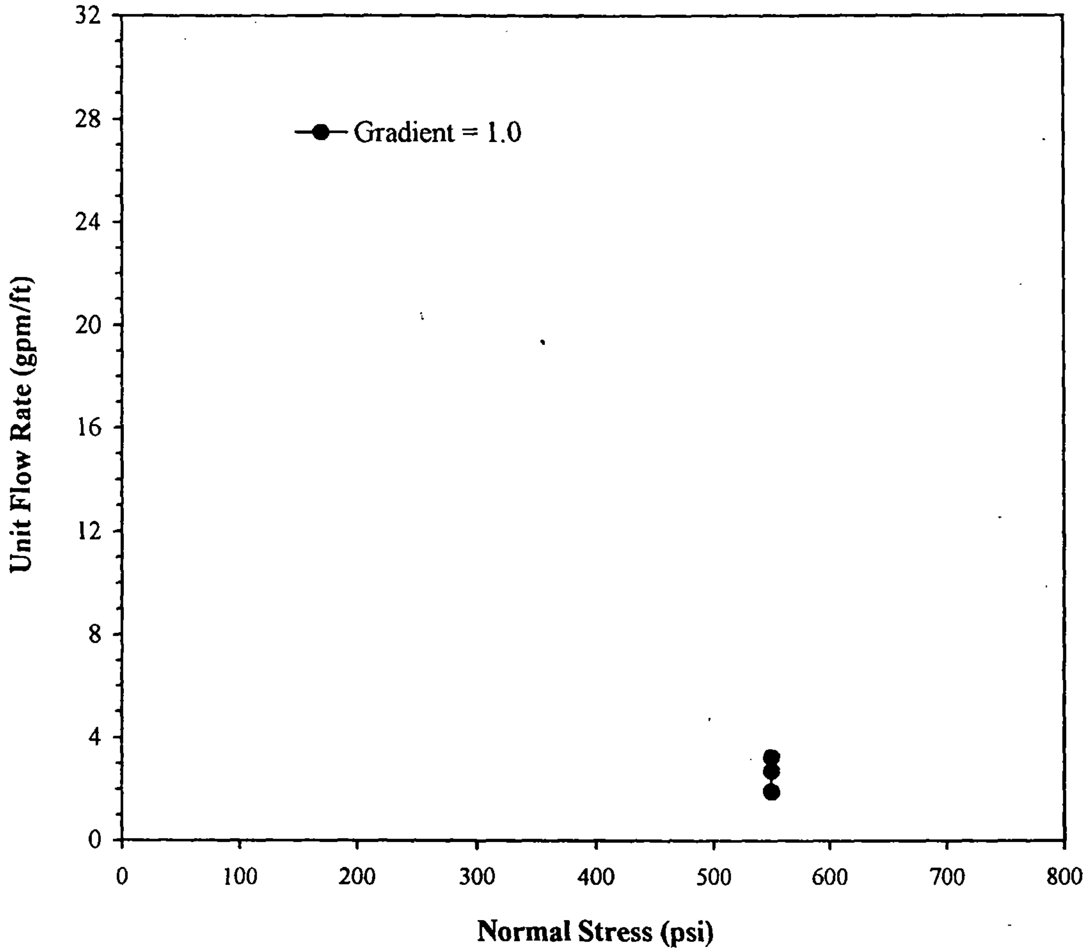
Laboratory temperature at 21±3 °C.

Test specimen final conditions are not presented.

APPENDIX C

HYDRAULIC TRANSMISSIVITY TEST RESULTS

AGRU/AMERICA, INC. - GILT EDGE MINE SUPERFUND SITE
HYDRAULIC TRANSMISSIVITY TESTING (ASTM D 4716)
COVER SYSTEM A
SGI Lab Sample ID: AL8911/AL9120/AL8914



Test No.	Flow Direction	Normal Stress (psf)	Seating Time (hour)	Hydraulic Gradient (-)	Transmissivity (m^2/sec)	Unit Flow Rate (gpm/ft)
1	Machine	550	0.25	1.0	3.91E-04	1.89
2	Machine	550	0.25	1.0	5.57E-04	2.69
3	Machine	550	0.25	1.0	6.69E-04	3.23
4						
5						
Average					4.74E-04	2.60

Notes:

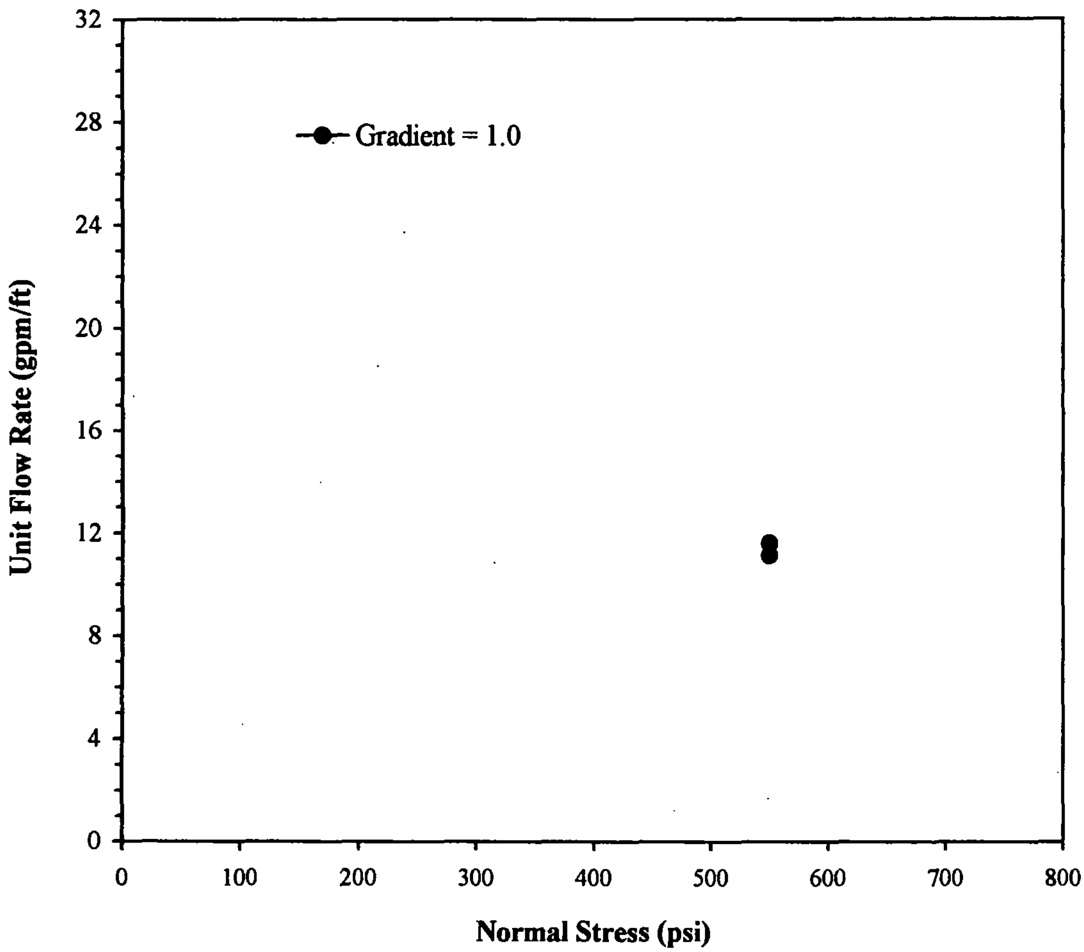
(1) Test configuration from top to bottom: top plate/Trachyte cover soil/TNS R080 nonwoven geotextile (heat-treated side down)/80-mil Agru Super Gripnet structured LLDPE geomembrane (cylinders side up)/sand and bottom plate.

(2) Test Specimen Dimensions: length: 12.0 in., width = 12.0 in.

SGI TESTING SERVICES, LLC

DATE REPORTED:	2/7/2002
FIGURE NO.	A-1
PROJECT NO.	SGI2018
DOCUMENT NO.	SGI02038
FILE NO.	

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE
HYDRAULIC TRANSMISSIVITY TESTING (ASTM D 4716)
COVER SYSTEM B
SGI Lab Sample ID: AL8911/AL8962/AL8938



Test No.	Flow Direction	Normal Stress (psf)	Seating Time (hour)	Hydraulic Gradient (-)	Transmissivity (m^2/sec)	Unit Flow Rate (gpm/ft)
1	Machine	550	0.25	1.0	2.31E-03	11.15
2	Machine	550	0.25	1.0	2.40E-03	11.62
3						
4						
5						
Average					2.36E-03	11.39

Notes:
(1) Test configuration from top to bottom: top plate/Trachyte cover soil/Tenax Tenflow 100-2 geocomposite/80-mil GSE textured LLDPE geomembrane/sand and bottom plate.
(2) Test Specimen Dimensions: length: 12.0 in., width = 12.0 in.

DATE REPORTED:	1/29/2002
FIGURE NO.	C-2
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

SGI TESTING SERVICES, LLC

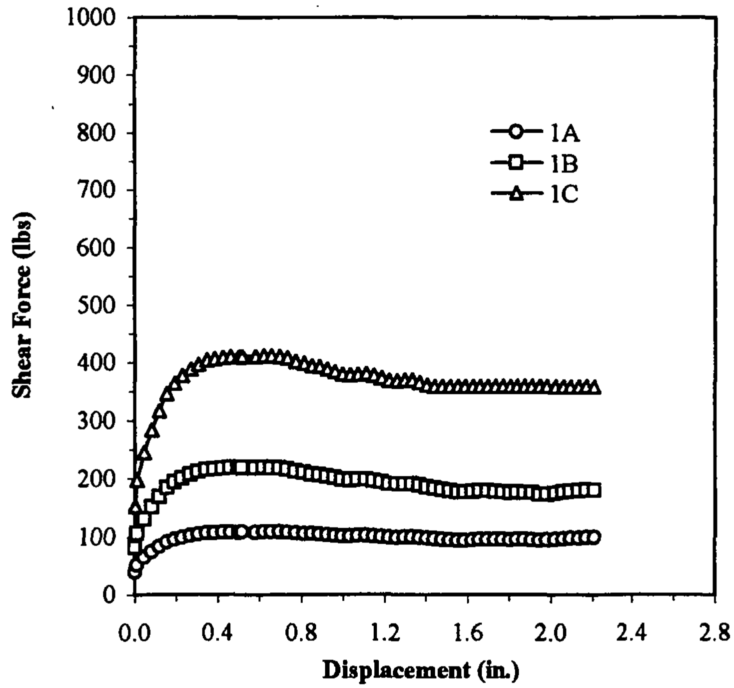
APPENDIX D

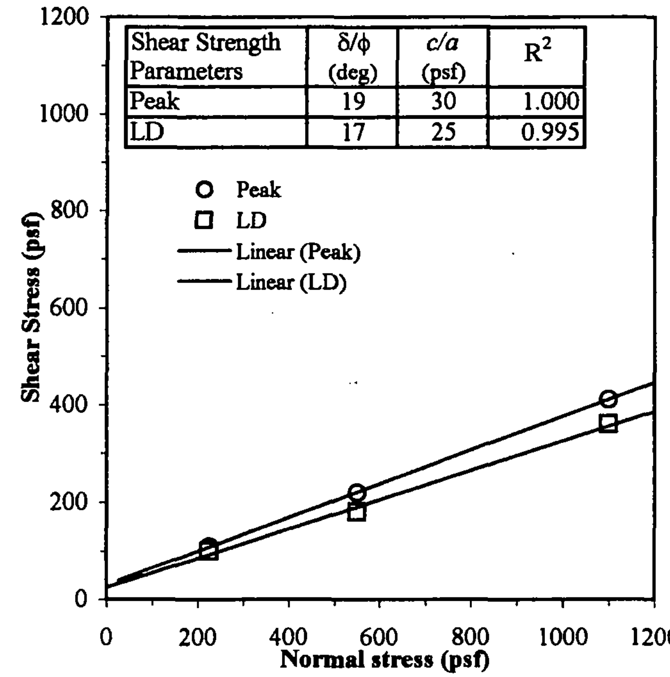
INTERFACE AND SOIL DIRECT SHEAR TEST RESULTS

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE

INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Test Series 1: Phyllite cover soil against Tenax Tenflow 100-2 geocomposite underlain by 80-mil GSE textured LLDPE geomembrane and processed ore under saturated conditions





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Lower Soil			Upper Soil			GCL		Shear Stress		Failure Mode
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_{di} (pcf)	ω_i (%)	ω_f (%)	γ_{di} (pcf)	ω_i (%)	ω_f (%)	ω_i (%)	ω_f (%)	τ_p (psf)	τ_{LD} (psf)	
1A	12 x 12	225	0.040	-	-	-	-	118.9	12.1	NM	106.4	0.4	NM	-	-	109	100	(1)
1B	12 x 12	550	0.040	-	-	-	-	118.8	12.1	NM	106.7	0.4	NM	-	-	220	180	(1)
1C	12 x 12	1100	0.040	-	-	-	-	118.9	12.1	NM	106.6	0.4	NM	-	-	412	360	(1)

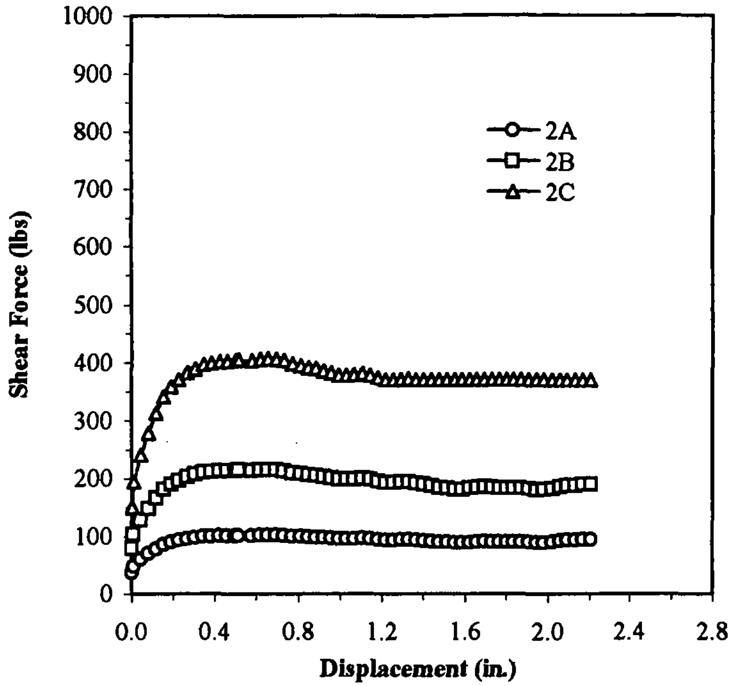
Notes: (1) Sliding (i.e., shear failure) occurred at the interface between the cover soil and geocomposite during each test. (2) NM - water content was not measured.
(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

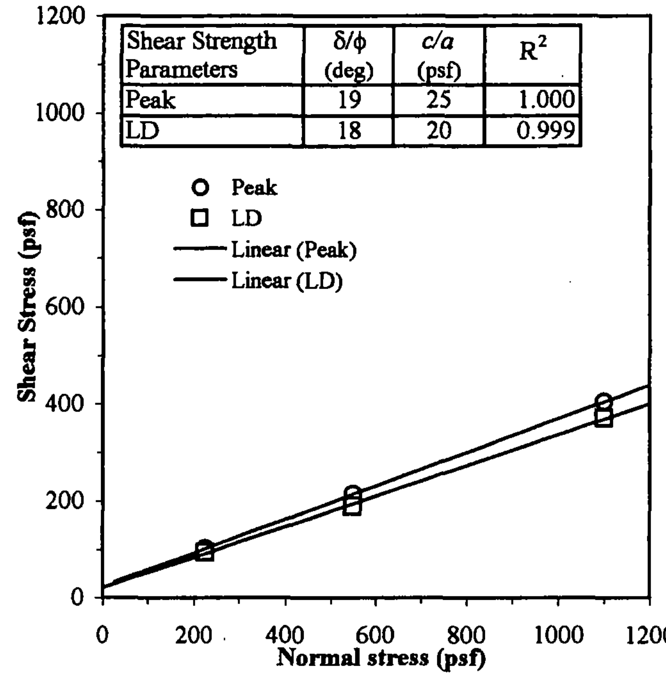
DATE OF TEST:	8 January 2002
FIGURE NO.	D-1
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

SGI TESTING SERVICES, LLC

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Test Series 2: Phyllite cover soil against TNS R080 nonwoven geotextile underlain by 80-mil Agru Super Gripnet structured LLDPE geomembrane and processed ore under saturated conditions





Shear Strength Parameters	δ/ϕ (deg)	c/a (psf)	R^2
Peak	19	25	1.000
LD	18	20	0.999

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Lower Soil γ_{di} (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_{di} (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_p (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
2A	12 x 12	225	0.040	-	-	-	-	118.7	12.2	NM	108.8	0.3	NM	-	-	102	95	(1)
2B	12 x 12	550	0.040	-	-	-	-	118.7	12.2	NM	106.6	0.3	NM	-	-	215	190	(1)
2C	12 x 12	1100	0.040	-	-	-	-	118.9	12.2	NM	106.7	0.3	NM	-	-	405	371	(1)

Notes: (1) Sliding (i.e., shear failure) occurred at the interface between the cover soil and geotextile during each test. (2) NM - water content was not measured.
(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

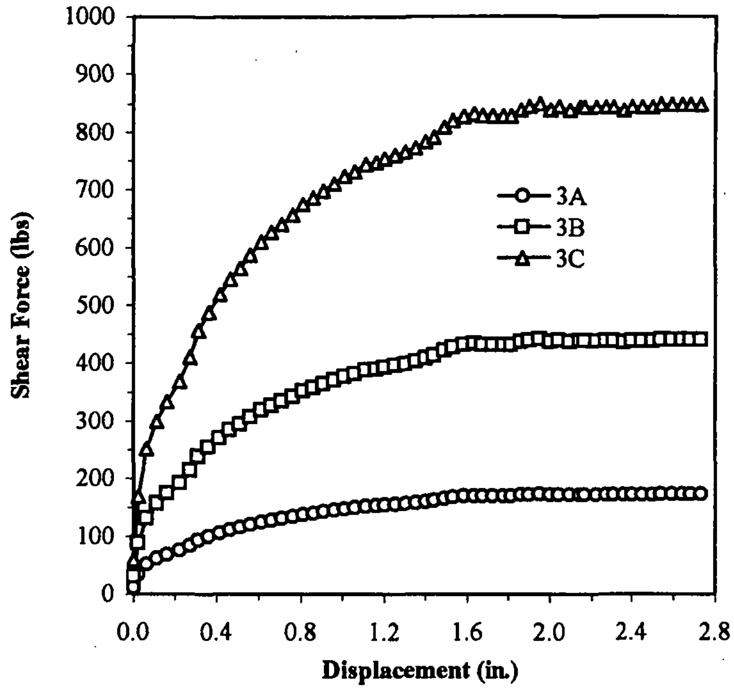
SGI TESTING SERVICES, LLC

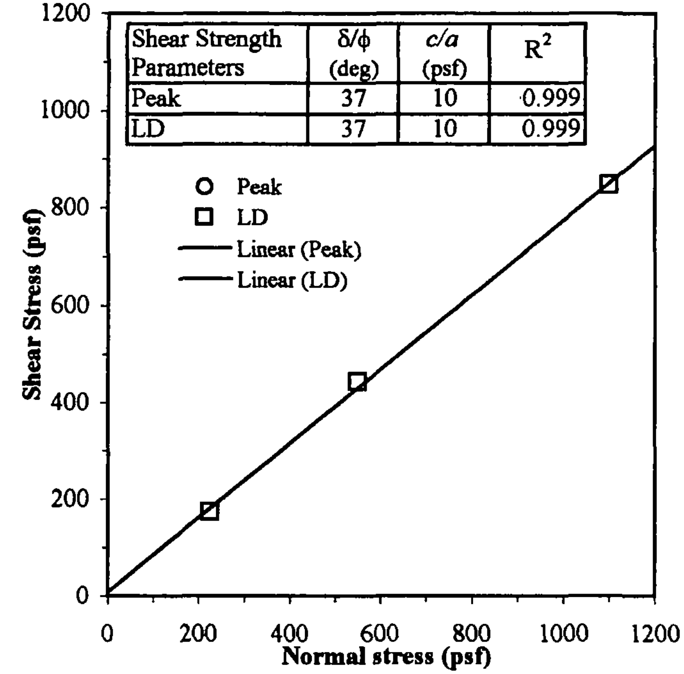
DATE OF TEST:	9 January 2002
FIGURE NO.	D-2
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE

INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Test Series 3: Trachyte cover soil against Tenax Tenflow 100-2 geocomposite underlain by 80-mil GSE textured LLDPE geomembrane and processed ore under saturated conditions





Shear Strength Parameters	δ/φ (deg)	c/a (psf)	R^2
Peak	37	10	0.999
LD	37	10	0.999

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Lower Soil γ_{dl} (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_{dl} (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_p (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
3A	12 x 12	225	0.040	-	-	-	-	119.0	12.0	NM	94.2	1.1	NM	-	-	174	174	(1)
3B	12 x 12	550	0.040	-	-	-	-	118.8	12.0	NM	94.4	1.1	NM	-	-	443	443	(1)
3C	12 x 12	1100	0.040	-	-	-	-	119.1	12.0	NM	94.3	1.1	NM	-	-	848	848	(1)

Notes: (1) Sliding (i.e., shear failure) occurred at the interface between the cover soil and geocomposite during each test. (2) NM - water content was not measured.
(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

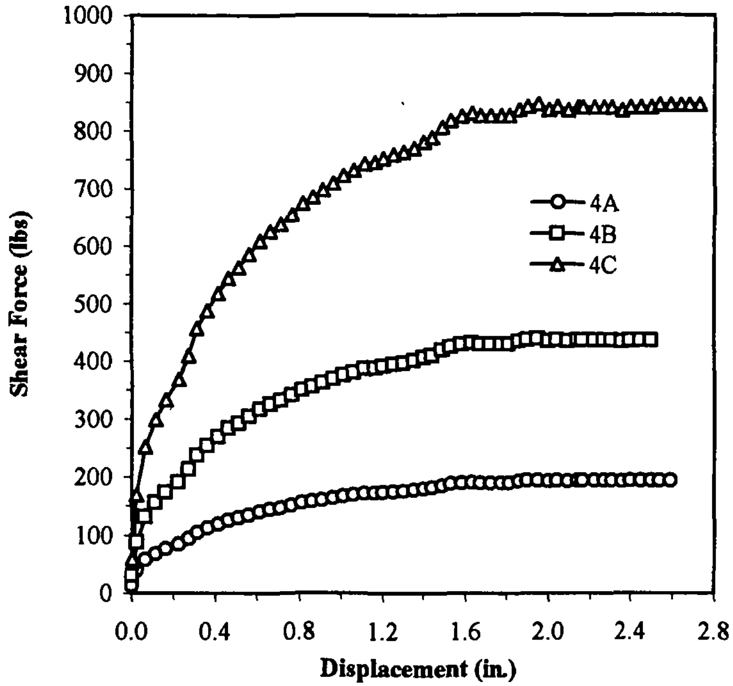
SGI TESTING SERVICES, LLC

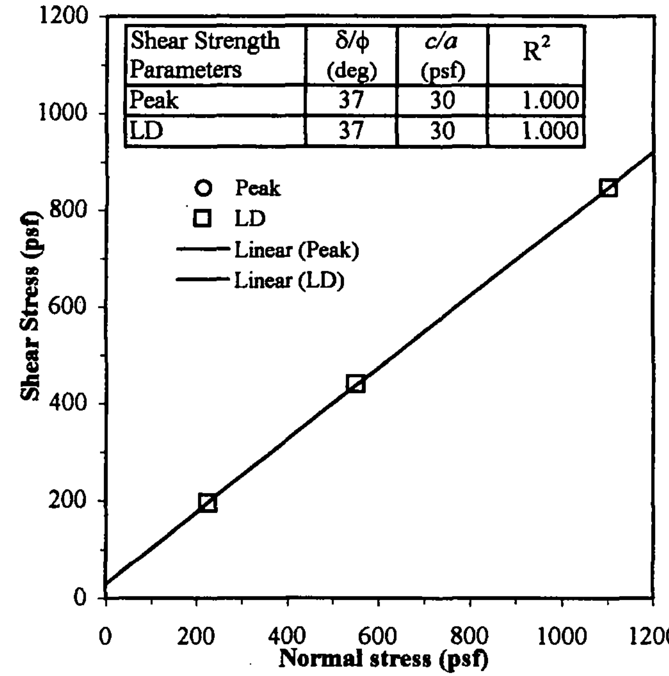
DATE OF TEST:	10 January 2002
FIGURE NO.	D-3
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE

INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Test Series 4: Trachyte cover soil against TNS R080 nonwoven geotextile underlain by 80-mil Agru Super Gripnet structured LLDPE geomembrane and processed ore under saturated conditions





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Lower Soil γ_{dl} (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_{dl} (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_p (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
4A	12 x 12	225	0.040	-	-	-	-	118.6	12.1	NM	94.7	1.0	NM	-	-	195	195	(1)
4B	12 x 12	550	0.040	-	-	-	-	118.8	12.1	NM	94.9	1.0	NM	-	-	440	440	(1)
4C	12 x 12	1100	0.040	-	-	-	-	118.7	12.1	NM	94.6	1.0	NM	-	-	846	846	(1)

Notes: (1) Sliding (i.e., shear failure) occurred at the interface between the cover soil and geotextile during each test. (2) NM - water content was not measured.
(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

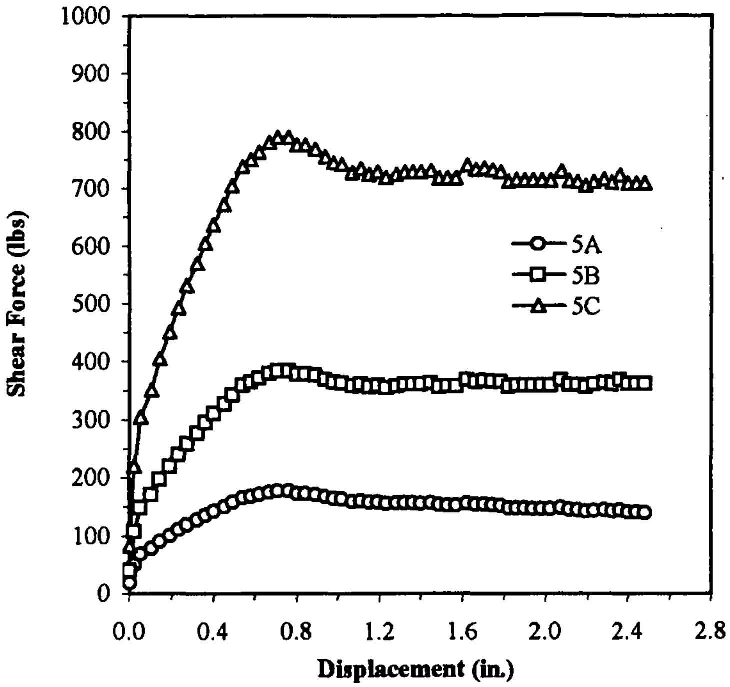
SGI TESTING SERVICES, LLC

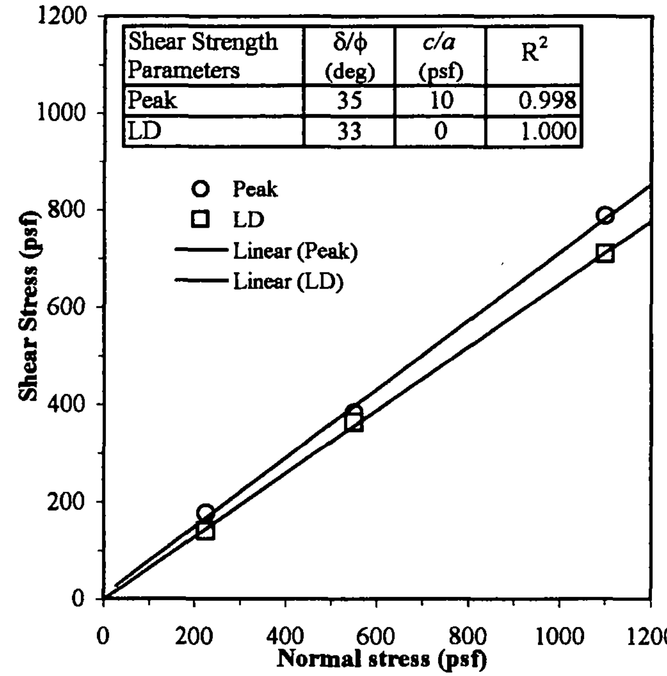
DATE OF TEST:	11 January 2002
FIGURE NO.	D-4
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE

INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Test Series 5: Deadwood Formation cover soil against Tenax Tenflow 100-2 geocomposite underlain by 80-mil GSE textured LLDPE geomembrane and processed ore under saturated conditions





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Lower Soil γ_{dl} (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_{dl} (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_p (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
5A	12 x 12	225	0.040	-	-	-	-	118.6	12.2	NM	101.7	0.4	NM	-	-	177	141	(1)
5B	12 x 12	550	0.040	-	-	-	-	118.5	12.2	NM	102.0	0.4	NM	-	-	383	363	(1)
5C	12 x 12	1100	0.040	-	-	-	-	118.8	12.2	NM	101.8	0.4	NM	-	-	789	710	(1)

Notes: (1) Sliding (i.e., shear failure) occurred at the interface between the cover soil and geocomposite during each test. (2) NM - water content was not measured.
(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

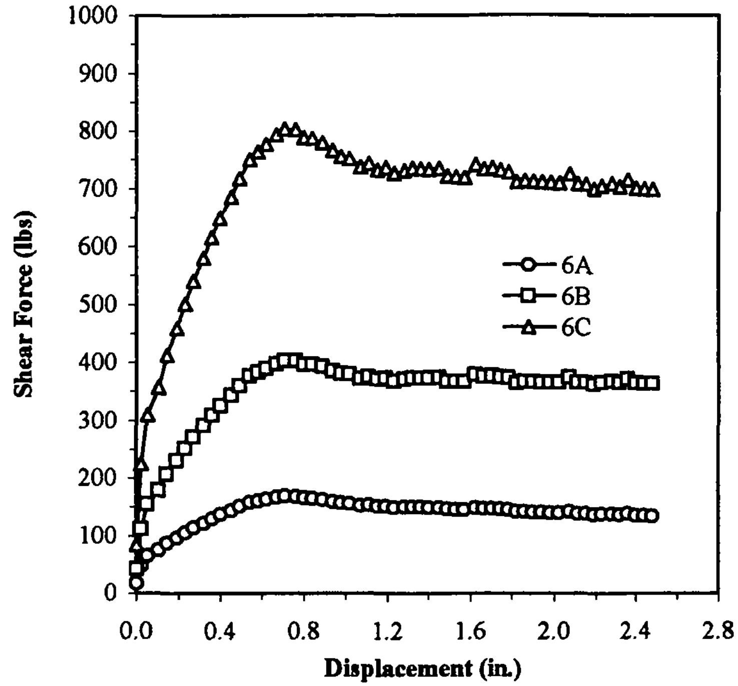
DATE OF TEST: 14 January 2002

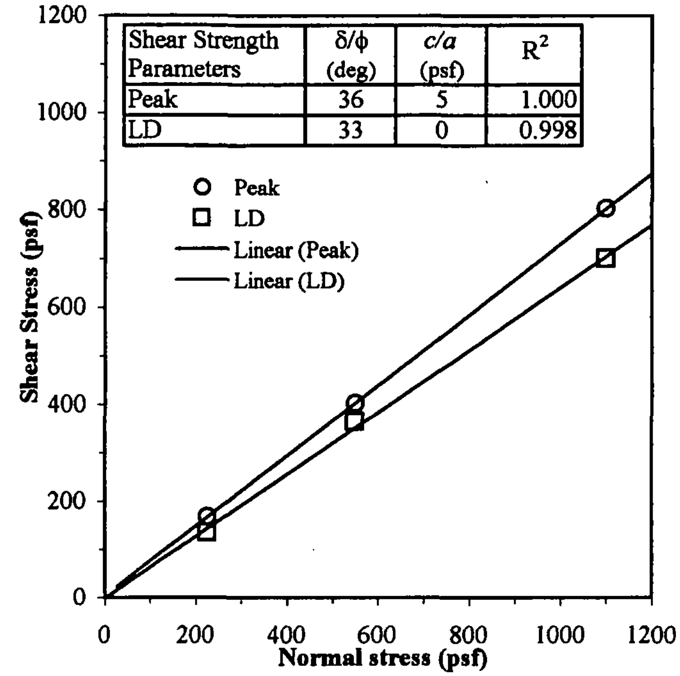
SGI TESTING SERVICES, LLC

FIGURE NO.	D-5
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Test Series 6: Deadwood Formation cover soil against TNS R080 nonwoven geotextile underlain by 80-mil Agru Super Gripnet structured LLDPE geomembrane and processed ore under saturated conditions





Shear Strength Parameters	δ/φ (deg)	c/a (psf)	R^2
Peak	36	5	1.000
LD	33	0	0.998

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Lower Soil γ_{di} (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_{di} (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_p (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
6A	12 x 12	225	0.040	-	-	-	-	119.1	11.9	NM	102.0	0.3	NM	-	-	169	135	(1)
6B	12 x 12	550	0.040	-	-	-	-	119.0	11.9	NM	102.2	0.3	NM	-	-	402	365	(1)
6C	12 x 12	1100	0.040	-	-	-	-	119.0	11.9	NM	102.2	0.3	NM	-	-	803	700	(1)

Notes: (1) Sliding (i.e., shear failure) occurred at the interface between the cover soil and geotextile during each test. (2) NM - water content was not measured.
(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

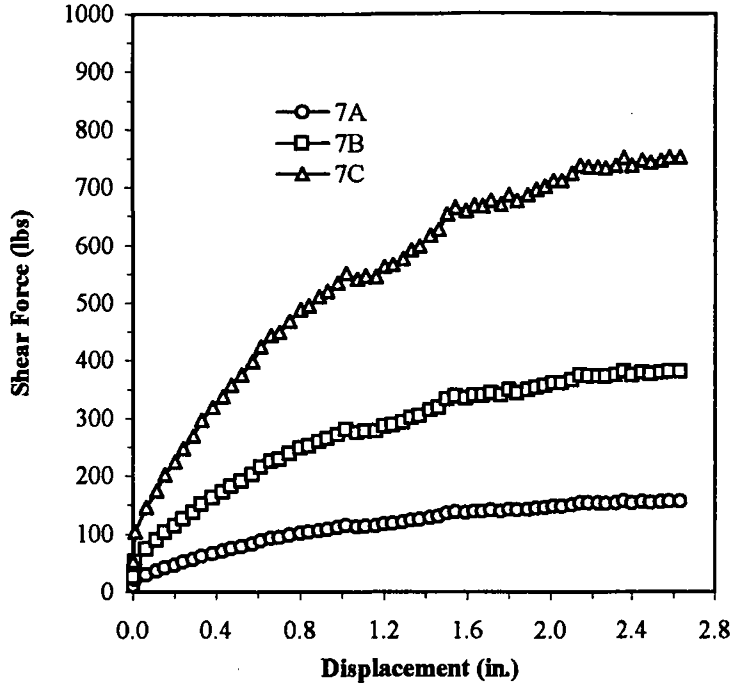
SGI TESTING SERVICES, LLC

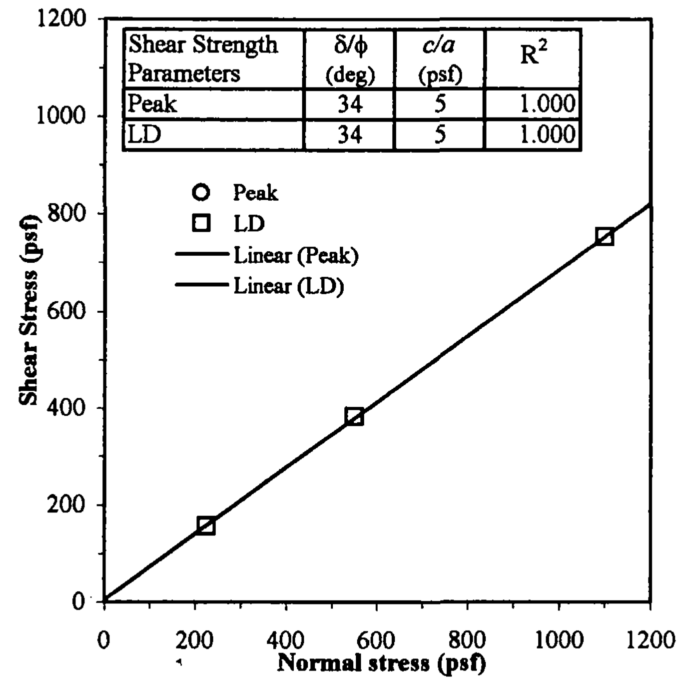
DATE OF TEST:	15 January 2002
FIGURE NO.	D-6
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE

INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Test Series 7: Porphyry/Latite cover soil against Tenax Tenflow 100-2 geocomposite underlain by 80-mil GSE textured LLDPE geomembrane and processed ore under saturated conditions





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Lower Soil γ_{dl} (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_{dl} (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_p (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
7A	12 x 12	225	0.040	-	-	-	-	119.3	11.9	NM	93.7	0.3	NM	-	-	157	157	(1)
7B	12 x 12	550	0.040	-	-	-	-	119.1	11.9	NM	93.9	0.3	NM	-	-	383	383	(1)
7C	12 x 12	1100	0.040	-	-	-	-	119.3	11.9	NM	94.0	0.3	NM	-	-	753	753	(1)

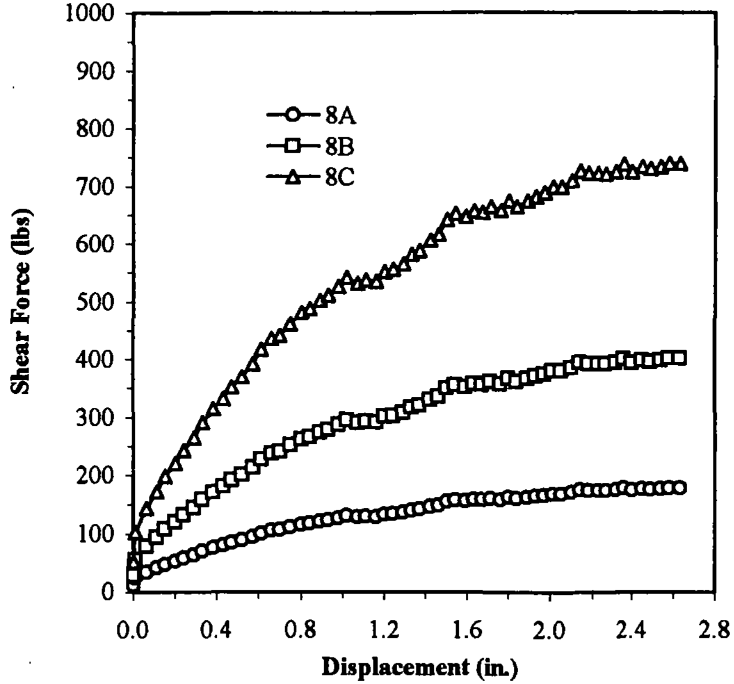
Notes: (1) Sliding (i.e., shear failure) occurred at the interface between the cover soil and geocomposite during each test. (2) NM - water content was not measured.
(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

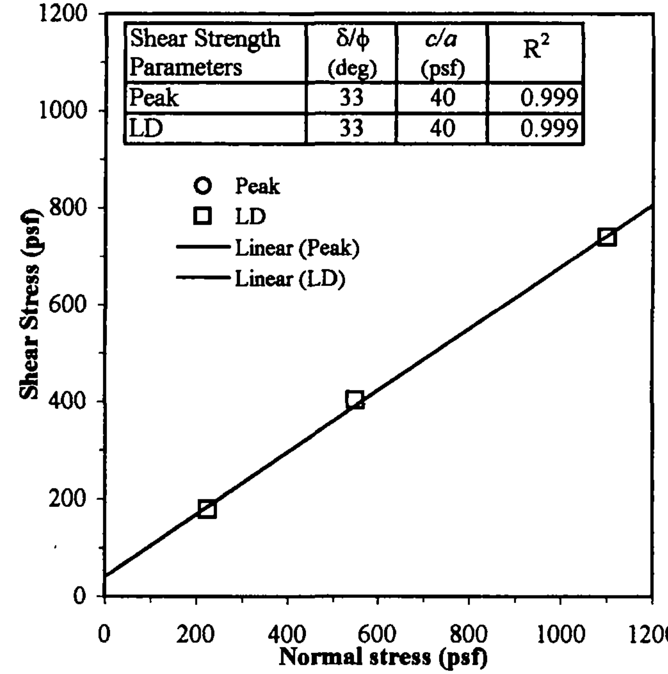
DATE OF TEST:	16 January 2002
FIGURE NO.	D-7
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

SGI TESTING SERVICES, LLC

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Test Series 8: Porphyry/Latite cover soil against TNS R080 nonwoven geotextile underlain by 80-mil Agru Super Gripnet structured LLDPE geomembrane and processed ore under saturated conditions





Shear Strength Parameters	δ/φ (deg)	c/a (psf)	R^2
Peak	33	40	0.999
LD	33	40	0.999

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Lower Soil γ_{dl} (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_{dl} (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_p (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
8A	12 x 12	225	0.040	-	-	-	-	119.0	12.0	NM	93.6	0.4	NM	-	-	179	179	(1)
8B	12 x 12	550	0.040	-	-	-	-	119.2	12.0	NM	93.4	0.4	NM	-	-	403	403	(1)
8C	12 x 12	1100	0.040	-	-	-	-	119.1	12.0	NM	93.5	0.4	NM	-	-	740	740	(1)

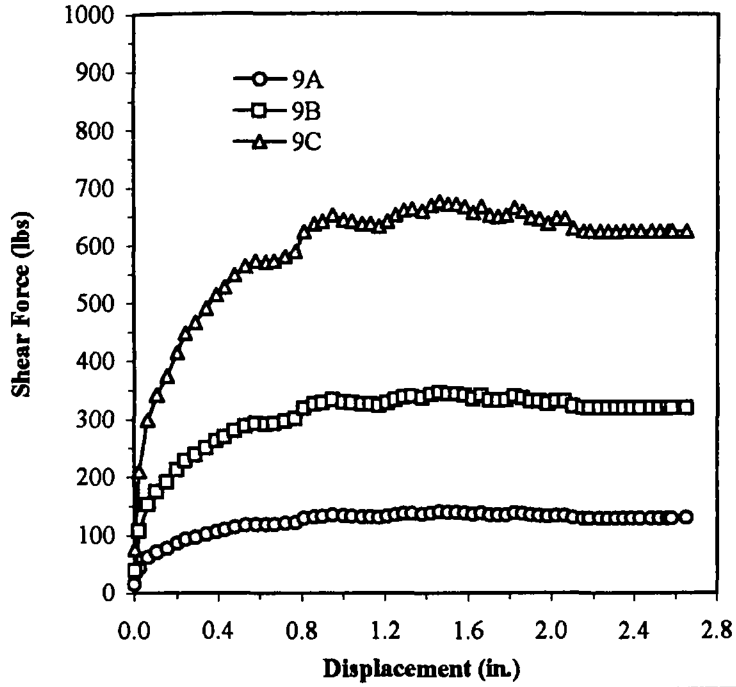
Notes: (1) Sliding (i.e., shear failure) occurred at the interface between the cover soil and geotextile during each test. (2) NM - water content was not measured.
(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

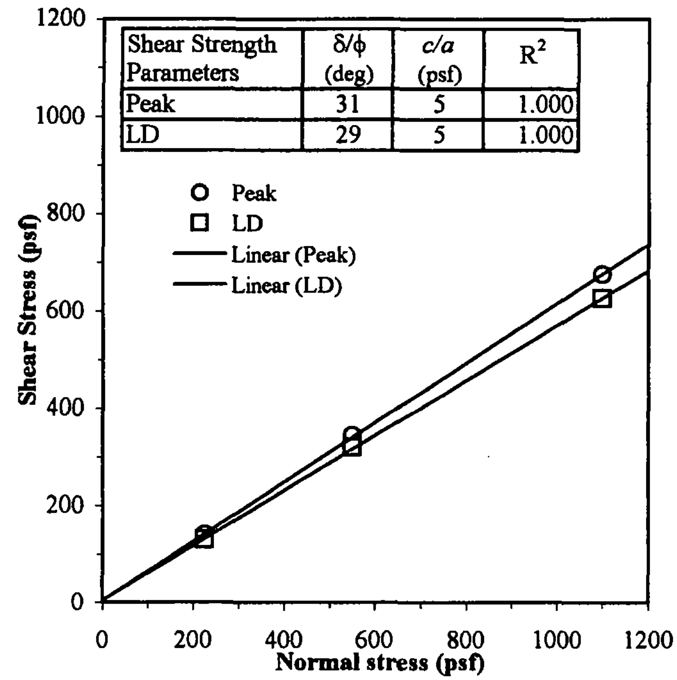
SGI TESTING SERVICES, LLC

DATE OF TEST:	17 January 2002
FIGURE NO.	D-8
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Test Series 9: processed ore against 80-mil GSE textured LLDPE geomembrane underlain by Tenax Tenflow 100-2 geocomposite and Trachyte cover soil under wetted conditions





Test	Shear	Normal	Shear	Soaking		Consolidation		Lower Soil			Upper Soil			GCL		Shear Stress		Failure
No.	Box Size (in. x in.)	Stress (psf)	Rate (in./min)	Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_{di} (pcf)	ω_i (%)	ω_f (%)	γ_{di} (pcf)	ω_i (%)	ω_f (%)	ω_i (%)	ω_f (%)	τ_p (psf)	τ_{LD} (psf)	Mode
9A	12 x 12	225	0.040	-	-	-	-	92.8	1.3	NM	118.7	12.3	13.9	-	-	140	130	(1)
9B	12 x 12	550	0.040	-	-	-	-	92.6	1.3	NM	118.9	12.3	13.2	-	-	345	320	(1)
9C	12 x 12	1100	0.040	-	-	-	-	93.0	1.3	NM	118.8	12.3	12.9	-	-	676	626	(1)

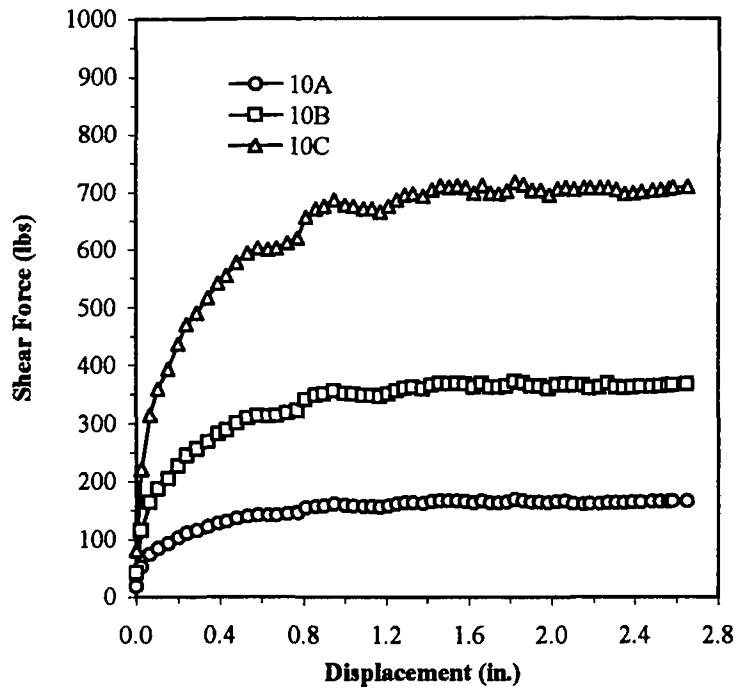
Notes: (1) Sliding (i.e., shear failure) occurred at the interface between the processed ore and geomembrane during each test. (2) NM - water content was not measured.
(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

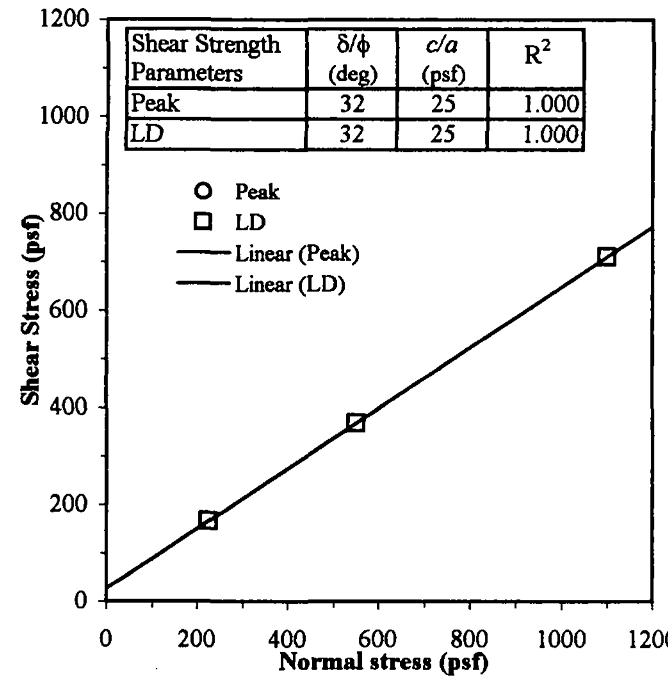
DATE OF TEST:	18 January 2002
FIGURE NO.	D-9
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

SGI TESTING SERVICES, LLC

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Test Series 10: processed ore against 80-mil Agru Super Gripnet structured LLDPE geomembrane underlain by TNS R080 nonwoven geotextile and Trachyte cover soil under wetted conditions





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Lower Soil γ_{dl} (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_{dl} (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_p (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
10A	12 x 12	225	0.040	-	-	-	-	93.1	1.1	NM	118.8	12.2	13.8	-	-	167	167	(1)
10B	12 x 12	550	0.040	-	-	-	-	93.3	1.1	NM	118.8	12.2	13.3	-	-	369	369	(1)
10C	12 x 12	1100	0.040	-	-	-	-	93.2	1.1	NM	118.6	12.2	12.8	-	-	711	711	(1)

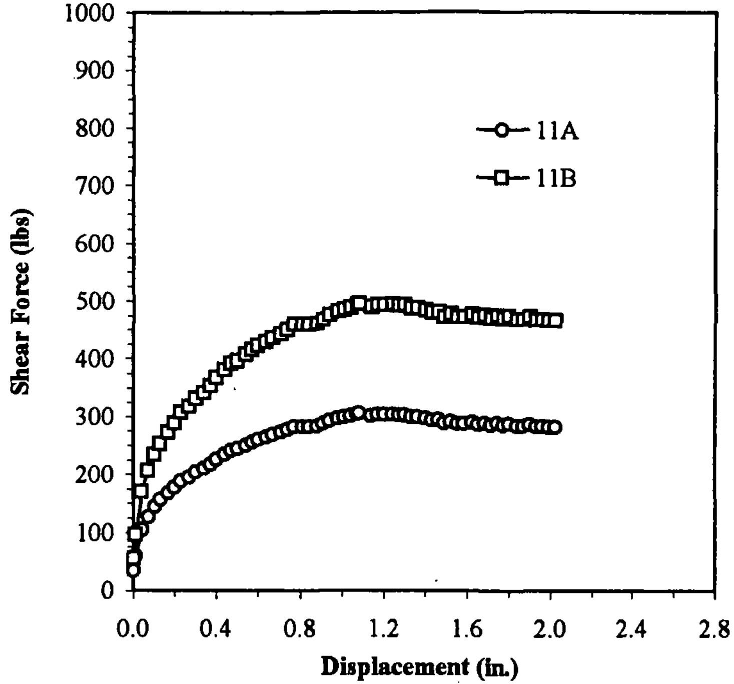
Notes: (1) Sliding (i.e., shear failure) occurred at the interface between the processed ore and geomembrane during each test. (2) NM - water content was not measured.
(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

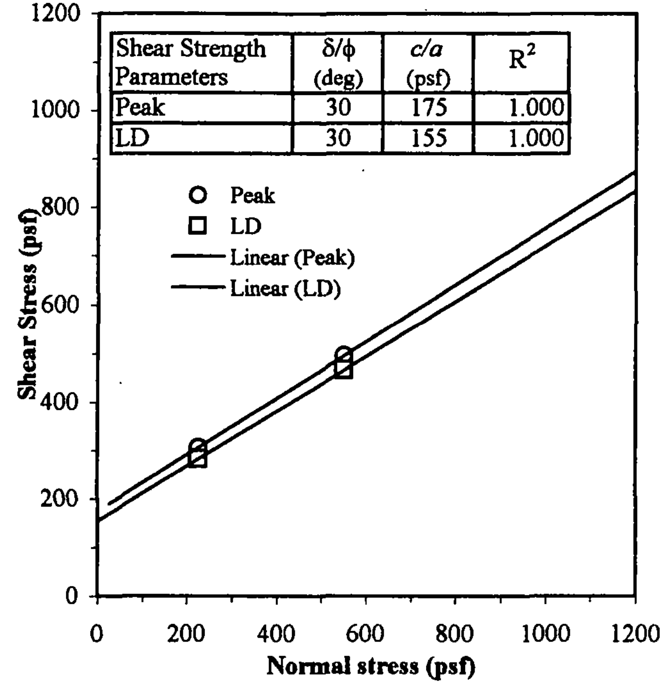
SGI TESTING SERVICES, LLC

DATE OF TEST:	19 January 2002
FIGURE NO.	D-10
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

U.S. BUREAU OF RECLAMATION - GILT EDGE MINE SUPERFUND SITE
INTERNAL DIRECT SHEAR TESTING (ASTM D 5321)

Test Series 11: internal strength of Phyllite cover soil under soaked conditions





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Lower Soil γ_{dl} (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_{dl} (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_p (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
11A	12 x 12	225	0.040	225	24	-	-	107.3	0.6	14.4	107.3	0.6	14.4	-	-	306	283	(1)
11B	12 x 12	550	0.040	550	24	-	-	107.5	0.6	14.1	107.5	0.6	14.1	-	-	496	467	(1)

Notes: (1) Sliding (i.e., shear failure) occurred at the mid-plane of the cover soil during each test.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

DATE OF TEST:	18 and 19 January 2002
FIGURE NO.	D-11
PROJECT NO.	SGI1105
DOCUMENT NO.	SGI02007
FILE NO.	

SGI TESTING SERVICES, LLC

Photo 1: Placement Of Trachyte Cover In Lower Shear Box

Photo 2: Another View Of Trachyte Cover

Photo 3: Placement Of Tenax Geocomposite

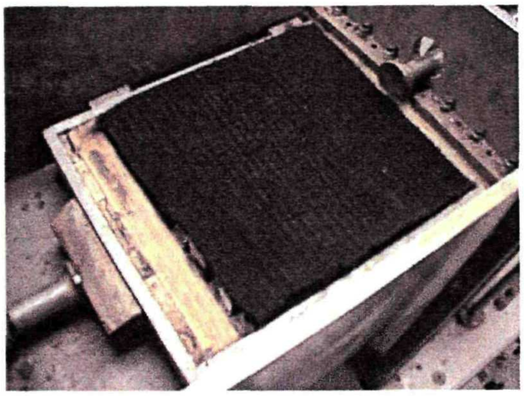


Photo 4: Top View Of Tenax Geocomposite

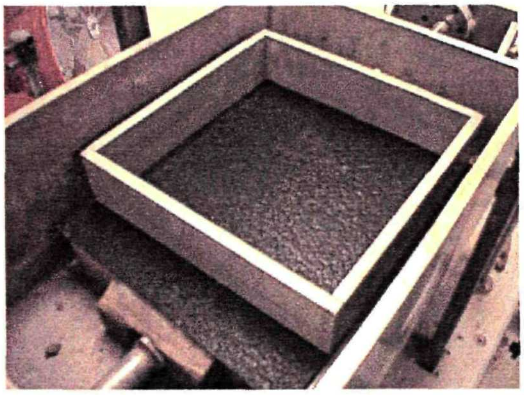


Photo 5: Placement Of GSE Textured Geomembrane

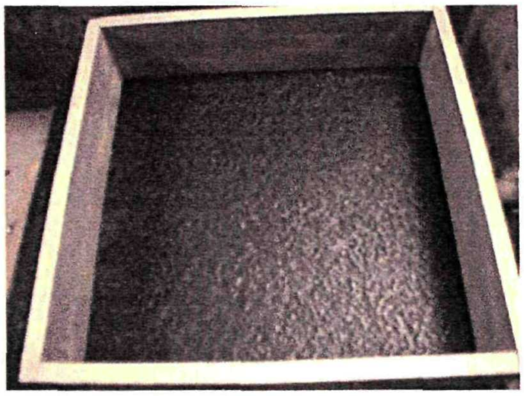


Photo 6: Top View Of GSE Geomembrane

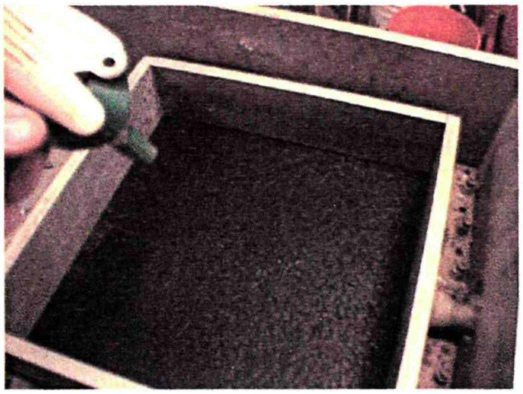


Photo 7: Wetting Of GSE Geomembrane

Photo 8: View Of Wetted GSE Geomembrane

Photo 9: Placement Of Processed Ore

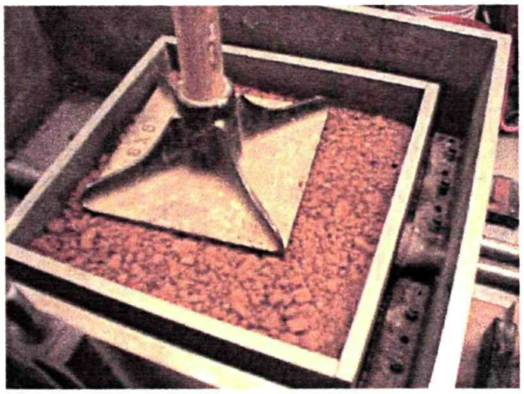


Photo 10: Compaction Of Processed Ore

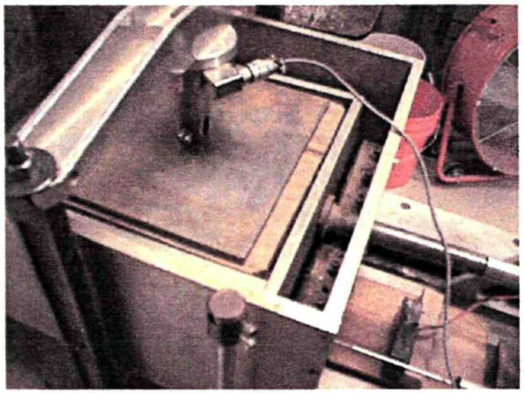


Photo 11: Completed Setup Of Interface Shear Test

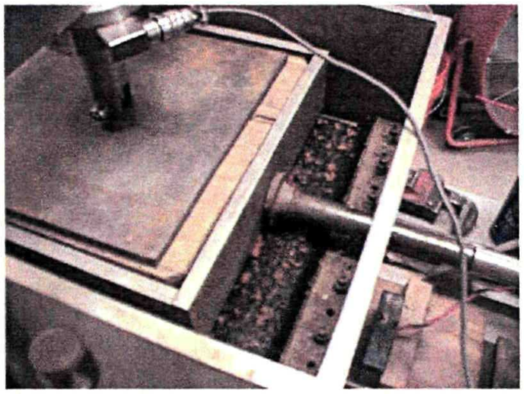


Photo 12: View Of Geomembrane Interface After Shearing

Photo 13: Test Series 1 Interface After Shearing At 1100 PSF

Photo 14: Test Series 2 Interface After Shearing At 1100 PSF

Photo 15: Test Series 3 Interface After Shearing At 1100 PSF

Photo 16: Test Series 4 Interface After Shearing At 1100 PSF

Photo 17: Test Series 5 Interface After Shearing At 1100 PSF

Photo 18: Test Series 6 Interface After Shearing At 1100 PSF

Photo 19: Test Series 7 Interface After Shearing At 1100 PSF

Photo 20: Test Series 8 Interface After Shearing At 1100 PSF

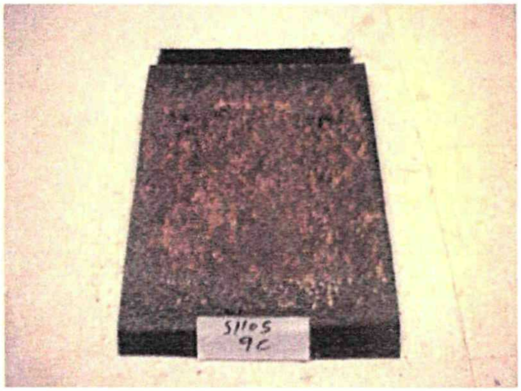


Photo 21: Test Series 9 Interface After Shearing At 1100 PSF

Photo 22: Test Series 10 Interface After Shearing At 1100 PSF

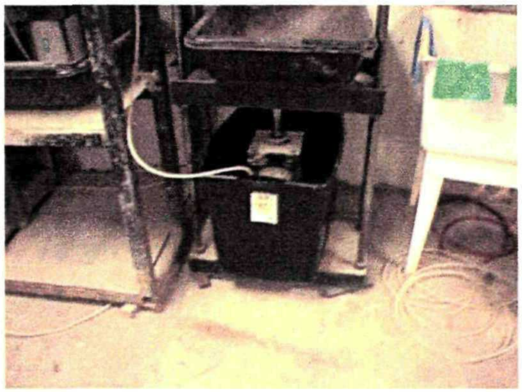


Photo 23: Soaking Of Phyllite Cover Soil For 24 Hours

Photo 24: Close-up Of Soaking Phase

Photo 25: Draining Of Water So Sample Can Be Transferred To Shear Box

Photo 26: Transferred Sample Into Shear Box

Photo 27: Another View Of Soaked Phyllite Sample Before Shearing

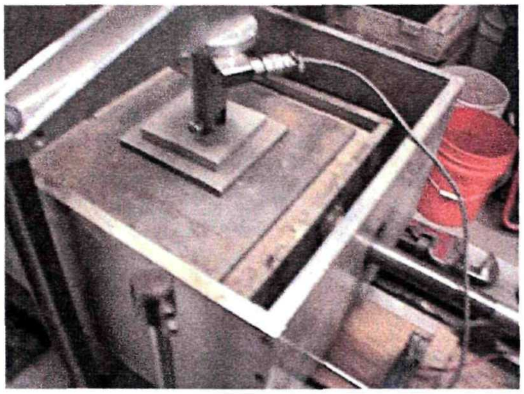


Photo 28: Completed Sample Set-up

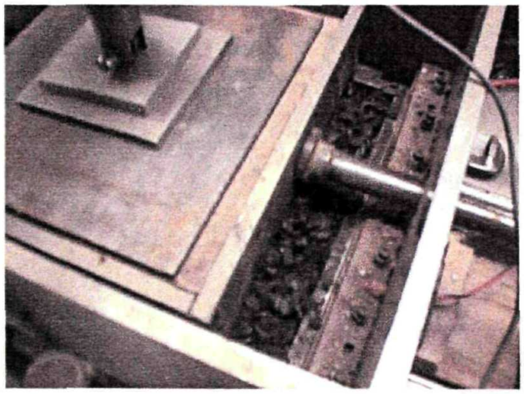


Photo 29: View Of Phyllite Cover Soil Being Sheared

Photo 30: View Of Phyllite Cover Soil Failure Surface

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